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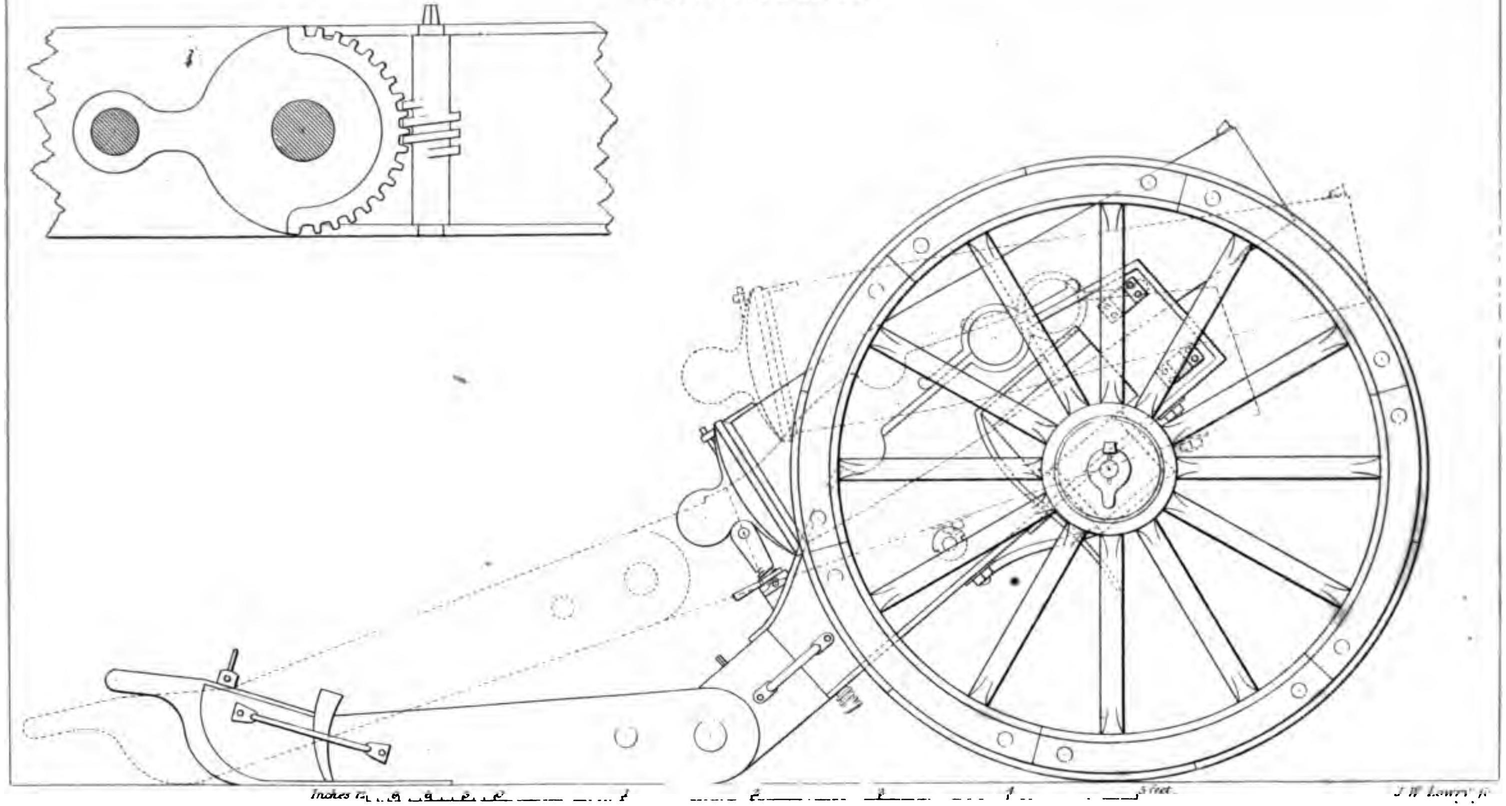

RIFLED ORDNANCE.

A PRACTICAL TREATISE

ON

THE APPLICATION

OF

THE PRINCIPLE OF THE RIFLE

TO

GUNS AND MORTARS

OF EVERY CALIBRE.

SECOND EDITION, *revised and corrected, with* ADDENDA.

BY Δυνάμικος.

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1857.

TO

HIS ROYAL HIGHNESS

THE DUKE OF CAMBRIDGE, K.G.,

&c. *&c.* *&c.*

COMMANDER-IN-CHIEF OF THE BRITISH ARMY,

This small Treatise,

IS, BY KIND PERMISSION,

MOST RESPECTFULLY DEDICATED BY

HIS ROYAL HIGHNESS'S

FAITHFUL HUMBLE SERVANT,

THE AUTHOR.

PREFACE TO THE SECOND EDITION.

In publishing a Second Edition of this little treatise, (in which various additions to, and alterations of the original text will be found,) I think it necessary to preface it with the remark, that the First Edition was intended for private circulation only; but that being subsequently induced to publish it, it appeared to me that certain passages might be rewritten or amplified with advantage. Beside these alterations, I have added various other matters connected with the subject, chiefly the result of experiments made by myself and others, and taken from notes and observations made at the time. In these addenda I have endeavoured further to explain, amongst other things, in what manner the principle of the rifle should, in my opinion, be practically applied to Heavy Ordnance, in order to produce the greatest and most useful results; and if the opinions expressed here do not meet with the entire concurrence

of those who are best informed upon the subject, the publication of them may, at least, induce other and perhaps abler persons to assist in the development of this interesting but difficult question, by furnishing the world with their own experience and opinions; for as yet we have no satisfactory or conclusive authority upon it to refer to,—mere theory, without practical experiment, here availing little or nothing. The absence of all such authority may partly plead as an excuse for any imperfections in this slight attempt to supply (in the meantime) the deficiency.

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INTRODUCTION.

As everything relating to the theory of projectiles is a matter for scientific enquiry and experiment, I deem no apology necessary for publishing such opinions as these have conducted me to, on what may be considered by some a purely military question. To pronounce upon the most proper method of *applying* any fresh discovery affecting that theory, is solely for the consideration of competent military authorities; and, if I have ventured to express any opinion on this point, I wish it to be understood, that it is under the correction of those who must be better aware of what is fit or unfit for practical purposes than I can possibly be. In other respects, however, I have advanced nothing which has not previously been well proved by experiment. Whatever opinions I have hazarded in the following pages, whether absolutely correct or not, may, therefore, be said to possess a certain value.

It is quite evident to all who have paid any considerable attention to the subject, that it is possible to produce a greater effect with cannon than has ever yet been obtained; still I must admit, after much investigation and many experiments, that the laws which appear to govern the new kind of projectiles to which I purpose directing attention,—that is to say, elongated shot, to be fired from rifle guns,—appear to be such as not to allow of any of those very startling results which are occasionally spoken of as possible.

The difficulties in the way of *perfecting* the construction of elongated shot and rifled guns are very much greater in the case of ordnance than in that of small arms. The want of sufficient strength of material, where a power of so uncontrollable a nature as that of a large charge of gunpowder is used, is an impediment to such an increase of effect as would otherwise, perhaps, be attainable.

Still it is possible to obtain very great results with rifled cannon, if constructed properly; and it was with a hope of discovering their capabilities, and how far these might be extended, that I turned my attention to the subject, and made my experiments. The latter have led me to certain conclusions, some of which

I have endeavoured to explain in the following pages, as I consider them of sufficient importance to lead to useful improvements in gunnery. They relate principally to the laws which should regulate the rifling of cannon, for the purpose of enabling them to throw a heavier description of shot or shell. This seems hitherto to have been determined more by caprice or fancy than by any fixed rules, so that, in fact, every rifled cannon has been an experiment.

My chief intention is to shew in what manner the principle of the rifle should (from a proper standard obtained in the first instance,) be applied to guns of all sizes, and thus cause a saving to Government of the expenses attending endless experiments, the cost of which, as personal experience has made me fully aware, is very great: should the results, however, of my experiments conduce in any way towards effecting the above object, it will be a gratification to know that the outlay has not been in vain.

RIFLED ORDNANCE.

OF RIFLED CANNON.

The advantages to be derived from the employment of cannon of this description are very great; for, not only is the deflection of the shot prevented, and greater accuracy obtained by their means, but, without increasing the weight of metal in the gun, it is possible to use with them heavier shot or shell than can be otherwise employed, and thus to obtain greater ranges. From a lack of knowledge respecting their capabilities, or owing to the want of sufficient data for establishing a fixed principle of construction, little success has hitherto attended their use, the idea of employing them in actual service not having been seriously entertained until a comparatively recent period.

Where the power of projection is limited, two methods may be employed for producing the greatest effect with projectiles; the one is by increasing their weight, and consequently causing a decrease in their velocity, and the other by diminishing their weight,

and thus increasing their velocity. A very superficial knowledge of gunnery will lead to the conclusion that the best effect is produced by increasing the weight rather than the velocity, particularly when the latter has reached a certain amount, since the laws of the resistance of the air preclude the attainment of any great advantage by giving a shot more than a certain velocity.

As it is not so much required in practice, however, to produce the greatest effect with a shot as with a *gun* of a given weight, the latter is the first to be taken into consideration. Now, as the production of great velocity requires heavy charges of powder, and greater thickness of metal in the gun, than is required for a proportionally increased weight of the shot, it will be advantageous to give additional weight to the shot even at the expense of its velocity. Let, as an example, two different kinds of guns used in the service, both of about the same weight, be taken; namely, a 32-pounder carronade, and a 9-pounder field piece. These exemplify the two cases, the latter throwing a 9 lb. shot 1400 yards at an elevation of 4°, and the former, with rather a smaller charge of powder, throwing a 32 lb. shot 970 yards at the same elevation. Here we see that the greater result is produced with the shot which is increased in weight, and not with that which has its velocity increased, (which the smaller of course has,) the carronade throwing a shot nearly four times the weight of the

other to two-thirds the distance, (and more, when the elevations used are greater), and that with a smaller charge of powder, the same weight of metal being required for both; indeed this latter point is still in favour of the carronade, the 9-pounder being of brass, and proportionably stronger.

Now, if with a gun of the same weight as either of these, a 32 lb. shot could, with the above elevation, be sent to a greater distance than the above-mentioned 9 lb. shot, it is undeniable that the means employed would be a sensible improvement upon existing arrangements. But even more than this can be accomplished by the use of elongated shot; that is, by the use of shot in which, while the weight is greater than that of spherical shot of the same diameter, the surface upon which the resistance of the air acts is the same, or nearly so. Although at elevations under three or four degrees the range of an elongated shot or shell of nearly four times its weight, may not, with its necessarily reduced charge of powder, be greater than that of a spherical shot of the same diameter, on account of the smallness of the *initial* velocity, combined with the shortness of the time of flight, yet beyond those elevations, owing to the greater weight of the elongated shot, which enables it to maintain a greater *mean* velocity, its range will be much greater than that of a spherical shot, as its curve of flight approaches more nearly to a parabola; so that a shell of

32 lbs. weight may be fired from a gun of about 12 cwt., with a 9-pounder bore, at 10° of elevation, with a charge of about 1¼ lbs. of powder, to a distance of more than 3000 yards. It would be difficult to say what its extreme range would be, when fired at its most effective elevation. I have never witnessed the experiment, nor has it, I believe, ever been properly tried; but I should think it would be more than double the range which it has at 10° of elevation.

This, I imagine, is about the greatest proportionate effect attainable (for practical purposes,) with a gun of the above weight, on account of the recoil, which would prevent the use of a much greater charge of powder, as well as from a want of strength in the metal of the gun. The charge of powder, however, for shot of the same diameter, but increased weight, may be reduced in a proportion about as the square root of the increase in their weight (that is, up to a certain point) with continually increasing effect; with even a greater reduction in the charge, they will (when fired above a certain elevation) range further than a round shot of the same diameter.

Wrought iron or steel might, perhaps, be employed with greater advantage in the construction of rifled field pieces than in that of any other description of gun, for, in all probability, it will be discovered that brass is not of a sufficiently hard nature to stand the wear and tear of heavy rifle shot for any length of

time. With regard to the strength of metal necessary, although the charge is much smaller in proportion to the weight of the shot where elongated shot are used, yet, owing to their greater weight, the strain upon that part of the gun where the shot receives the first impulse from the powder is, of course, great, especially with expanding shot; this, however, may be considered as the only part requiring any material accession of strength. It will be observed that in the form of gun shewn in the large figure of the frontispiece to this volume, the outline from the breach to the trunnions is a curve; the object of this is to give the greatest strength to that part of the gun where it is most required, without increasing its weight; with rifled guns this is a point which more particularly requires consideration, from the fact that elongated shot may be fired with effect at greater elevations than round shot.

The great drawback to the use of elongated shot lies in the absolute necessity of giving them a rotary motion about their axes, in order to cause them to fly truly, and to keep their axes coincident with their lines of flight; and however objectionable the use of compound shot may be in some respects, this renders the employment of them obligatory, for it is impossible that long, homogeneous, and unexpanding shot (of iron at least) can be made to truly describe a given line of flight, on account of their not filling the bore sufficiently to prevent them from shifting their position in the gun when on the point of quitting it. As this

drawback, however, is not felt in using, but in *storing* them, it appears to me that it might be overcome (as shells alone need be used) by storing them in cases. The expense of this would not be very enormous, and the advantages to be gained by their use are certainly sufficient to remove any impediment of this nature.

OF THE TURN OF THE RIFLING.

IN the construction of rifled cannon (perhaps from the circumstance that the laws by which it should be regulated have not hitherto been properly investigated) scarcely sufficient importance seems to be attached to the determination of the turn or pitch to be given to the grooves—a point upon which, in reality, failure or success almost entirely hinges; and it is remarkable that no one, as yet, has attempted any discovery or definition of the laws by which that determination should be regulated, for, however much opinions may differ on this head, it is tolerably clear that there must be some fixed laws, applicable to guns of every variety of calibre, by which this matter should be governed.

Although the object I have more immediately in view is not so much to determine the proper amount of turn which should be given to shot of various kinds, as to explain the principle by which the grooves of guns of all sizes should (by means of a correct standard) have the proper turn assigned to each according to its calibre, still it will be well, in the first instance, to consider upon what circumstances the length of

turn to be given to the grooves of a rifle is dependent.

It will be superfluous for this purpose to enter into a discussion of all the laws relating to projectiles; those only need be brought under notice which bear more immediately upon the point in question.

First, then, it should be noted that the force of projection caused by the explosion of the powder ceases to act upon the shot directly it leaves the gun.

Secondly,—That the flight of the shot will depend upon the force of projection exerted upon the shot, the resistance of the air, and the weight and form of the shot; for it will (if the elevation be sufficient to prevent it from being prematurely drawn to the earth by the action of gravity) continue to move until the retarding force of the air has destroyed the *vis viva* generated by the projecting force, and the amount of this retarding force will wholly depend (for a given velocity) upon the extent and form of the surface of the shot.

Thirdly,—That although the onward flight of the shot, and the rotary motion about its axis, are two distinct movements, yet, the rotary motion being imparted by means of the grooves during the shot's passage out of the barrel, the velocity of rotation is necessarily dependent upon the velocity with which it is projected. Any increase, therefore, in the velocity of rotation, when obtained by increasing the *turn*

of the grooves only without increasing the charge of powder, is acquired at the expense of the velocity of the onward flight, because an additional portion of the projectile power is expended in overcoming the increased friction.

Fourthly,—A certain velocity of rotation is required to keep a shot perfectly true to its proper line of flight, and the turn of the grooves must be such as to give it this velocity of rotation throughout the *whole* flight, otherwise it would only be sufficient to carry it with a proper degree of accuracy for a certain distance.*

Fifthly,—That the velocity of the shot's rotation, being dependent upon that of its onward flight, will continue to vary mainly in proportion as the latter is greater or less; and any cause, such as the pressure of the air, a want of density, or other circumstance, which has a tendency to retard the flight of the shot,

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* It might appear to some, at first sight, that if there is imparted to the shot an initial velocity of rotation sufficient to keep the axis of the shot coincident with the line of flight when the resistance of the air is greatest—that is, at the first portion of the flight—it will not be possible for that velocity to be too much reduced during the flight. But this is not the case; for, as the velocity of rotation is a function of the velocity of translation, it is evident that as the latter becomes considerably diminished (in consequence of the retardation produced by the air) the former *may* undoubtedly be reduced below the *minimum* velocity that is necessary to preserve the coincidence above referred to.

will always check its rotary motion also, for the pressure by which it suffers retardation, acting upon the whole opposing surface of the shot, the retarding, as well as the propelling force, is experienced by each motion in the same relative degree.

Assuming these propositions to be correct, it will follow that the degree of turn calculated to produce the best effect, is that which will be just sufficient to keep the axis of the shot coincident with its line of flight throughout the whole period of its range. (This more especially applies to rifled cannon, with which, in throwing percussion shells, considerable elevations may be used with effect.) It will also follow that this turn will vary as the shot vary in form and weight. If these observations are admitted to be just, I believe I shall experience but little difficulty in establishing my theory for regulating the turn to be given to the grooves, as they form its chief basis.

I have a few remarks to make respecting the turn of the rifling in small arms, and the manner in which it is affected by the use of various kinds of bullets, and will then proceed to describe the effect produced upon it by an increase in the size of the bore of the gun; and it will be seen that, although great advantages may be derived from the employment of rifled cannon, yet the laws which should regulate the turn of the grooves are of a nature to discountenance any very exaggerated notions of what may

be accomplished. The effect is, indeed, slightly diminished (in comparison with the size of the gun) as the calibre increases.

In small arms, where the ordinary bullet of about an ounce weight is used, the question as to the best turn to be given to the grooves, appears to be settled in favour of a whole turn in about thirty inches; but touching that which is best for elongated shot, opinions somewhat differ, although more in appearance than reality. In spite of the apparent diversity of opinion on this subject, it will be found upon examination, that it is chiefly the difference in the weight and shape of the shot which causes one rifle to shoot better with a less, and another with a greater turn. If the proper length of turn were fixed by a correct standard, according to the weight and shape of the bullets used, the existing disparity between the turns of different rifles would be accounted for, since the same laws must equally govern both.

The shape and weight of the shot are undoubtedly the first subjects for consideration in this matter, as having a direct influence upon the required nature of the turns. For when a shot of fixed weight is to be fired with a given charge, the only way of increasing the velocity of rotation is by the employment of a greater turn; therefore, as a general rule, whatever tends to check that velocity, such as the form of the shot offering great resistance to the air, the want in the shot of a certain density, &c., will necessitate the

use of a greater turn, proportional to the additional velocity of rotation required to be given.*

In the absence of all data concerning the effect

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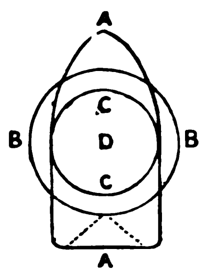
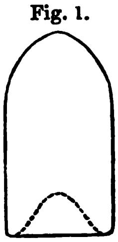
* If the reader will cast his eye upon the accompanying figure,



he may see whence it arises that the ordinary-sized elongated shot requires less turn than the spherical shot of the same weight. AA represents an outline longitudinal section of an elongated shot of the same weight as the spherical shot, whose central section is BB; and CC is the circumference or outline of a transverse section of the elongated shot A, the centre of gravity of each being at their centre of figure D. The elongated shot AA having a considerably less diameter than BB, not only offers a much less portion of its surface before its centre of gravity to the direct resistance of the air than the spherical shot, which has all the resistance upon its fore part, but the pressure of the air upon that portion of AA behind its centre of gravity tends to give it stability. The turn required for the elongated shot would be much less, were it not that the pressure of the air upon its longitudinal surface retards its rotary motion in some measure, and that, owing to its diameter being smaller than that of the spherical bullet of equal weight, the rotary impetus is not so great as with the latter; from these circumstances it happens that when their length is much increased, the whole retarding force of the air upon their rotary motion is so much increased in comparison to that which opposes their progressive movement (and the additional weight being in their length only, adds but little to their rotary impetus,) that it will then be necessary to use with them a turn as great as, or even greater than, that which would be sufficient for the shots BB or CC. It is impossible to give the exact amount of turn rendered necessary by these differences; experiment alone will shew this in the first instance.

produced by different kinds of shot with rifled guns of large calibre, let us observe the different effects of the variously shaped bullets now in use upon the turn in small arms. The most celebrated are Pritchett's, (which is used with the Enfield rifle, and has entirely superseded the Minié and a host of other,) Major Jacob's, and, I may also mention, that used for Colt's pistols. I have taken these as examples of the opposite means employed (namely the great and small turn) for producing the greatest effect.

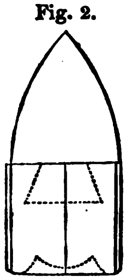
Fig. 1.



Pritchett's.

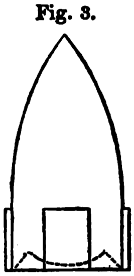
The Pritchett bullet (Fig. 1), is about two diameters in length, and of a cylindro-conoidal form. It is homogeneous, but its form is such that it has its centre of gravity thrown slightly forward; it is used with a rifle (the Enfield), having a turn in 6 ft. 6 ins., and a bore ·577 in. in diameter.

Fig. 2.



Jacob's.

Fig. 3.

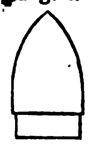


Jacob's.

Major Jacob's bullets (Figs. 2 and 3), are not quite so heavy, and more nearly approach a conical form. They have four projections, which fit the grooves, and are necessary, I believe, to prevent the bullet stripping, on account of the great turn used with it. The fore part of the bullet is of zinc or steel, and its centre of gravity is in the hind part; it is fired from a rifle

having a turn in 24 ins. (or in some cases 36 ins.) only, the diameter of the bore being the same as in the preceding instance.

Fig. 4.



Colt's.

The bullet used with Colt's pistols (Fig. 4), approaches the form of Major Jacob's, but has no projections or steel point; a similar turn is required for the two, and with Colt's, a heavier charge of powder than is commonly used for a pistol is employed.

Here then, at first sight, appears an unaccountable disparity in the turn employed; but if attention be paid to the difference of form in the bullets, it will be perceived that there are three or four very sufficient reasons why that of Major Jacob should require a greater turn than Pritchett's.

In the first place, on account of its zinc or steel point, Major Jacob's has somewhat less density than Pritchett's, and therefore, the retarding force of the air diminishes its velocity more rapidly. Secondly—Its form being so much more conical, it offers a greater surface to the direct resistance of the air to its rotary movement.* Thirdly—The position of its centre of gravity is such that it would require a greater velocity of rotation to be given to it, in order to preserve its proper direction and overcome its inclination to turn over, as its want of stability would be in proportion

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* See also Note, page 47.

to the distance that its centre of gravity is behind the centre of its figure. Fourthly—The projections formed upon it, cause a greater displacement of the air in the act of rotation than in the other bullet.

Each of these circumstances unquestionably affects the flight of the shot, and therefore exerts more or less influence upon the turn; yet, notwithstanding this fact, we frequently find persons advocating the employment, some of a greater and others of a less turn, either as their fancy seems to dictate, or from considerations altogether unconnected with the form of the bullet: if, however, what I have stated be correct, the length of the turn should depend entirely upon the weight and form of the shot employed, some shot requiring a greater, and some a less turn. The first question therefore to be taken into consideration is the *form* of shot with which the greatest effect can be obtained? And I think no one will deny that the advantages lie together on the side of that which requires the least turn. Simple representations as to the range and accuracy of certain shot, unaccompanied by a complete statement of *all* the circumstances attending their trial, prove little or nothing. It has been stated that Major Jacob can with his bullet strike an object with a certain degree of force at a much greater distance than has been attained with Pritchett's; but I think it is questionable whether it would do more if both were fired with the same velocity, and at the same elevation; for if the Pritchett bullet has

sufficient turn to keep it straight during its whole flight, it must have a greater random range than Major Jacob's, on account of its superior momentum, and of the angle of the turn required for it being less, as also from its form offering less resistance to the air. The steel point in Major Jacob's bullet may possess some advantages, where it is a question of firing leaden bullets with great velocities; but that has nothing to do with the application of the rifling principle to cannon, and in other respects the advantages appear to be considerably in favour of the form of the Pritchett bullet, as more conducive to great range, and also as requiring a less turn,—two very important considerations.*

* It would perhaps, be advantageous, as all troops of the line are, or probably will be, armed with the Enfield musket, to furnish the Rifle Brigade with a rifle having a shorter and stouter barrel, to carry a bullet of the same diameter, but a trifle heavier, and to be charged with a rather heavier charge of powder; the friction would be reduced, and a greater range might be obtained, and if the turn in 6 ft. 6 ins. were found insufficient to keep the bullet true during its longer serviceable range, the turn might be increased in proportion. By this means the effective range of small arms might be carried to its utmost limit. I would suggest that the barrel be of the same weight as the present, but 30 inches only in length, having a turn in 60 inches, and charged with $2\frac{3}{4}$ drachms of powder, and a bullet weighing 20 drachms. This would be a much handier weapon than the present, and would secure greater precision of fire at long distances, and in the hands of the Rifles would ensure precisely those advantages in respect to range, &c., over the Minié musket, which that corps should be furnished with.

A great obstacle to the employment of shot requiring a very great turn, is the increased friction produced, and the danger of their stripping; and on these grounds it is imperative to make use of the least possible turn as a standard in applying the principle of the rifle to guns of large calibre; for it should be borne in mind, that it is the great turn which requires the heavy charge of powder*—where great ranges are required—on account of the velocity of the shot's rotation bearing a greater proportion to the velocity of its flight than when the turn is less, so that if the charge of powder were not in proportion to the turn, its range would be diminished. A greater turn than is needful is moreover attended with disadvantages arising from the necessary use of increased elevations, and from an increase in the lateral action of the wind upon the shot, owing to the consequent increase in its time of flight.

To have too small a turn, however, is a fault on the wrong side; for when a great velocity of translation is given to a shot where the turn is insufficient, since the velocity of its rotation suffers an amount of retardation proportionate to that of its onward flight,

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* This is correct in theory; but, on account of the danger of the shot stripping, can only to a certain extent be practically carried out; it is true that, under certain circumstances, a slighter turn *may* be used with a heavy than with a light charge, but for point blank distances or low elevations only.

as soon as the latter is checked the former becomes insufficient to preserve the coincidence between the axis of the shot and the line of flight after a certain distance is passed over, and therefore accuracy of fire at long distances is rendered impossible. This is a result which must, of course, be avoided, since with rifled guns great accuracy is the first thing to be secured, and extent of range the next.

As some modification of the turn will be found necessary in all cases where the shot materially differ in form and weight, it must be supposed, before entering into any explanation respecting the relative turn to be employed for guns of different calibres, that the description of projectile and the turn most suitable for it when fired from a gun of a certain calibre have first been decided upon; these being ascertained, I propose shewing in what manner the turn should be modified to suit each calibre, upon any alteration taking place in the size of the bore of the gun.

Hitherto, in rifling cannon the two extreme methods appear to have found the most favour; the one consisting in giving the grooves a length of turn of about the same number of diameters of their bore as in a rifle carrying an ounce ball; the other in giving them a turn of scarcely more than the same length as the turn of an ordinary rifle; no satisfactory reason—that I have ever heard of—being assigned for either system. Those who advocate the giving to

guns of large size of a turn proportioned to the diameters of their bore, (for example, twice the length of turn for a gun of a calibre double the diameter of another,) appear to forget the fact that, although the proportions of the gun may remain the same, the circumstances attending the projection of the shot—its velocity, time of flight, range, resistance to the air, &c.—will all be in a different ratio to each other in the case of the larger gun, to what they are in that of the smaller, and that *all* these have to be considered. I have proved the fallacy of both extremes by frequent experiments, in a manner which leaves no doubt upon my mind on the subject; but as I am about to give an explanation of that which I consider to be the correct mode of ascertaining the proper length of turn for guns of all sizes, it will be unnecessary for me in this place to state the reasons which led to the conviction on my part that both the above methods were erroneous.

For the present, therefore, I will assume that they are so; there must, in that case, be between the two extremes a mean amount of turn which is the best, and which must likewise vary for guns of every calibre, supposing the same description of shot to be used with all. I will endeavour to explain in what way this important point may be determined; and I think it will then be admitted that the proper turn for each gun will differ according to its calibre, and that the common method of assigning a certain turn—such as

a third or a fourth of a turn in the whole length of the bore—to all guns, irrespective of their length and calibre, is as erroneous a practice to follow as either of those which I have already mentioned.

Every one who has any knowledge of the ranges of shot of different sizes, must be aware that a shot of eight times the weight, or of twice the diameter of another, has, when fired with the same velocity as that other, a greater range than it by nearly one-half, and that this increased range is owing to the weight of the larger shot being increased in a greater proportion than the surface which it offers to the resistance of the air.* This circumstance is noticed by Robins in his Tracts on Practical Gunnery,† an extract from

* If two round shots of the same density are projected from the same place, with the same velocity, and in the same direction, their ranges will depend upon their sizes alone, because both the work accumulated in each, and the retarding force of the air exerted upon each (which alone destroys the work), will themselves depend upon the sizes alone (the velocity not being regarded); and beside these elements—the work accumulated and the retarding force—there is nothing to be considered. Now the work varies as the weight, and therefore as the *cube* of the shot's diameter, while the retarding force varies as the surface (nearly), and therefore as the *square* of the shot's diameter. Consequently, as the size of the shot is increased, the work accumulated is increased in a much greater proportion than the retarding force, and therefore the range will also be increased in a considerable proportion.

† In Robins's Tracts, page 256, he observes that—" A 24-pr. loaded in the customary manner and elevated to 8°, ranges its bullet at a medium to about a mile and a half, whereas a three pounder,

which I have given below. In this, however, the effect produced by the difference in size of the two shot is noticed only in general terms; but for the purpose I have in view, it will be necessary to examine the subject a little more closely.

According to Dr. Hutton, the increase in the resistance to shot, is about $\frac{1}{30}$th part more than as the squares of their diameters. This, then, in a shot double the diameter of another, would cause the resistance of the air to be over four times as much, and its weight being increased eight times, the proportion of the increase in the retarding force of the air upon it, to the increase in its weight, would be rather more than one-half, and its range would in consequence be about

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which is half the diameter, will, in the same circumstances, range but little more than a mile; and the same holds true in the other angles of elevation, though indeed, the more considerable the angle of elevation, the greater is the inequality of the ranges. Now this diversity in the range of unequal bullets cannot be imputed to any difference in their velocities, since, when loaded alike, they are all of them discharged with nearly the same celerity, but it is to be altogether ascribed to the different resistances they undergo during their flight through the air: for, though a shot eight times the weight of another has four times the resistance, yet, as it has eight times the solidity, the whole retarding force which arises from the comparison of the resistance with the matter to be moved will be but half as much in the larger shot; and thus it will always happen (whatever be the size of the shot) that the retarding force of the air on the lesser shot will be greater than the retarding force on the larger, in the same proportion as the diameter of the larger shot is greater than the diameter of the lesser."

as 1·46 to 1, when compared with that of the smaller,* or rather more than the square root of 2, (2 being the number expressing the multiple which the one diameter is of the other;) that is, when fired at their most effective elevations, and with any but extremely low velocities. For though when subject to the pressure of the atmosphere, the increase of weight (or momentum) and surface (or resistance) in the larger shot, will exhibit a difference in their relation one to another, according to the velocities with which they are fired (owing to the nature of the resistance of the air), yet the ratio which they bear to those of the

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* For although the resistance of the air suffered by a shot twice the diameter of another in size, is but half in quantity compared with the increase in its weight, and it might therefore be supposed (as inferred by Robins) that the retarding force of the air, and therefore its range, would be in proportion to its diameter, or double that of the smaller; yet the retardation produced by the air is not decreased in the same proportion, for were the *weight* only of the shot to be increased eight times, its surface remaining the same, the extra range due to this addition in its weight would not be even three times greater (which is rather more than as the square root of the increase in its weight,) under the most favourable circumstances. But in the case where shot are of increased size but the same density, the resistance of the air being likewise increased in the proportion of one-half the quantity of the increase in their weight, the real increase in their range will not (except when fixed with very low initial velocities) be more than one-half of that which it would acquire from an increase in its weight alone, or about half as much again as that of shot half their size, however great the elevations used.

smaller will always remain the same, for the retarding influence of the air upon the shot's flight, is always *proportionately* less as its size is increased, its velocity being the same; and although the range of a shot, when subject to the influence of the air, will not be in due proportion to its velocity, as would be the case were it fired in vacuo, yet it will always be according to the proportion which the surface and weight of the shot bear to each other.

We will now consider what effect the relative increase in the weight and size of shot will have upon the turn, in rifling guns of large calibre.

Experiment has shewn that a certain velocity of rotation is necessary to insure the correct flight of shot, and I think it must be admitted, theoretically, that all shot of similar forms, of whatever size, if of the same density, and fired with equal velocities, supposing the retarding force of the air to be in exactly the same proportion to their weight, would require the same velocity of rotation to insure their stability. For a shot, if fired in vacuo, would require no rotary motion whatever, because, whether it had such or not, it would continue its flight in the position and direction in which it left the gun, with no resistance whatever upon it. The resistance of the air being, therefore, the only cause which renders the rifling necessary, whatever tends to lessen this resistance, will allow a proportionate decrease to be made in the velocity of the shot's rotation. Consequently, if its density or weight

be increased, without increase in its surface, the retarding force of the air will be lessened in proportion; but if an increase, corresponding to its increase of weight, be made in its surface, the effects will neutralize each other. But the resistance of the air, of course, differs with the diameter of the shots, and therefore, as whatever tends to check the velocity of their onward flight must necessarily check the velocity of their rotary motion, and as we have seen that the retarding force of the air is proportionately less upon larger shot by nearly one-half where the diameters are double, the turn of the grooves can only be decreased for larger shot in that proportion. But as the resistance of the air is not quite one-half less, and as the friction caused by the deeper indentations on the surface of the larger shot must, although slight, be in some measure considered, I have calculated that the decrease in the turn should be (instead of 1·46 to 1, as stated before) as 1·41 to 1, or as the square root of 2, (2 being the number expressing the ratio of the greater diameter to the smaller,) which comes very near the exact proportions, and is a much more simple calculation.

I should notice that any increase in the size of elongated shot will, owing to their form, cause the pressure of the air to be experienced in rather a greater proportion than with spherical shot; but as this increase of pressure will be counteracted by the increased *vis viva* of rotation, consequent upon the increase in its diameter, and as the ranges do not appear to be

affected by it, the above calculations need not be altered on this account.

The point to which it will next be necessary to turn our attention, relates to the comparative effects which the production of different velocities has upon shot of different sizes, and whether these should have any influence upon the turn in adapting it to guns of larger calibre. In the foregoing extract from Robins's Tracts on Practical Gunnery, he remarks that the difference of the retarding forces of the air, upon the two shot instanced, is more appreciable as the elevation of the gun is increased; and he alludes to the cause to which this is to be attributed, namely, the different effects of the resistance of the air upon the increased surface and weight of the shot, occasioned by the variation in its velocity as its range becomes more extended; but he does not notice the effect caused by firing the shot with different *initial* velocities.

In firing with high velocities, we find that at point-blank distances, the ranges of shot shew an increase of only about one-fourth in shot double the diameter of others, and that this increase gradually becomes proportionally greater as the elevation of the gun is increased, until, finally, the increase in the range of the larger shot over that of the smaller, when at their most effective elevations, is augmented by nearly one-half.

But this difference again varies when very low initial velocities are used. Upon examining the

results of various experiments where shells have been employed, it will be seen that, when fired from mortars with a charge of powder not exceeding a fortieth part of their weight, and at an elevation of 45°, they will have ranges almost as their diameters. This would give the larger of the two shot a range of just double the distance of that of the smaller, instead of only one-half more, as in the former instance, where higher velocities were supposed to be used.

It appears therefore that the increase in the extreme range of the larger shot over that of the smaller, varies (in these two instances) from nearly one-half as much again to twice as much, according to the different velocities with which they are fired; and at point-blank distances, where the velocities are greatest, the increase is only one-fourth.

From this it follows that the retarding force of the air (the amount of which we can only estimate by the range) is in a greater proportion to the size of the shot in the larger than in the smaller, as their velocity is increased. This is because the resistance of the air (which increases as the squares of their diameters as well as of their velocities) becomes *comparatively* greater upon the surface of the larger shot as the velocity is increased; consequently, when the latter is high, the ranges of the larger shot will shew less difference when fired at low elevations, but when fired at their most effective elevations they will always exceed those of the smaller in proportion to

the ratio of their weights to their diameters, as they will then pass through every degree of velocity. With low initial velocities, therefore, the effect produced by increasing the size of shot is much more apparent.*

The question we have now to consider is, whether the different effects produced by greater or less velocities, upon shot of different sizes, should occasion any alteration in the rule already given for assigning the proper turn to each shot.

I think it will be quite unnecessary to prove any further that the retarding force of the air (which has a certain limit,) is always *proportionately* greater upon the smaller shot than on the larger, with whatever velocity they are fired, (supposing that to be the same for each,) and that the variation in the retarding force of the air upon them, as shewn by their ranges, will only materially differ from that which I have assigned as due to their respective weights and surfaces, when the velocities are extremely low. Their ranges, commencing with very low velocities, (such as would be produced by using a charge of about the fortieth part of the weight of the shot, or about 400 feet a second,) would appear to shew a difference at first nearly as their diameters; but, as the retarding force of the air increases so rapidly with any increase in their velocities, upon any increase in the latter, the

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* See Note, page 87.

corresponding difference in their extreme ranges speedily becomes less until it reaches the point where the difference between the ranges is in proportion to their weights and diameters, or about half as much again in a shot twice the diameter of another; and it will always exceed the range of the smaller in this proportion, whatever the velocities may be with which they are fired, for the resistance of the air is such that, the higher the velocities the more quickly the initial effect upon both shot is reduced. For this reason an increase in velocity beyond a certain degree produces a very slight effect upon the whole flight of the shot, during which it has to pass through every degree of velocity between the initial and final velocities.

Taking various other circumstances into consideration, I see no reason however for making any alteration in the proportion of the turn already given for shot of increased diameter, on account of any increase or decrease in their velocities; for if sufficient velocity of rotation is given to a shot to keep it perfectly true during the whole period of its extreme flight, when fired with its most effective velocity and elevation, every contingency is provided against.

There are two distinct circumstances to be considered in giving the proper rotary movement to shot; the one is the pressure of the air upon the fore part of the shot, when it is at its greatest velocity during the first period of its flight, which causes it to require a certain velocity of rotation in order to

preserve its stability; and the other is the want of perfect concentricity or homogeneity in the shot, arising from any defect in the material or make, and this must always exist in a greater or less degree, and is much more apparent when the velocities are low than when they are high.

Experiment has shewn that we may give a shot sufficient velocity of rotation to preserve its stability during the first period of its flight, while that velocity may not, upon the decrease in its onward velocity, be sufficient to prevent its deflection, after passing over a certain space. Now, the action of the air being the only cause of a shot requiring any rotary motion whatever, that which would be sufficient for it when subject to the greatest pressure would, theoretically, always be enough to enable it to maintain a proper degree of truth throughout its whole flight, as the velocity diminished. This deflection therefore may arise from either, or both of the above-mentioned circumstances: namely, either from too great a retardation of its rotary movement at the first period of its flight, caused by the displacement of the air (or friction), arising from the inequalities of its surface; or from a certain want of homogeneity; in conjunction probably with the fact, that a shot with the slowest progressive movement imaginable may possibly require a certain velocity of rotation in order to preserve its proper position against the influence of the action of gravitation and the unequal pressure of the air consequent upon it; like a hum-

ming-top, which, without having any progressive motion whatever, always requires a certain velocity of rotation to be given to it to enable it to maintain its equilibrium when placed in a certain position; and although the pressure of the air upon a *shot* (in consequence of its progressive movement) would be increased as the square of the velocity with which it is projected, and its rotary motion might therefore be supposed to require some acceleration to meet this resistance, yet as its velocity of rotation (the same turn being used) is increased in proportion to the velocity of its propulsion, and as the latter suffers an almost equal amount of retardation from the influence of the same opposing force—the pressure being consequently as rapidly reduced—the turn which is sufficient for a low progressive velocity may be considered sufficient to give to a shot the necessary velocity of rotation when the former is increased; that is to say, to any extent that would be required for practical purposes.*

* When however the initial velocity of rifle shot exceeds a certain limit, (about 1200 feet a second, but less, as the length of the shot is increased,) the pressure of the air upon their longitudinal surfaces, as well as the actual friction caused by the indentations or projections on their surfaces, will have a considerably greater retarding effect upon their rotary, than upon their progressive movement; so that, when fired at considerable elevations, the former will not (owing to the retardation which it must undergo at the first period of its flight) retain the necessary *vis viva* to keep the shot steady after passing over a certain space. At lower elevations this

We may conclude, then, that the velocity of rotation which will be sufficient to keep a shot true, during its most extended flight, will be sufficient for any initial velocity that may be used; and although we find that when low initial velocities are employed, the retarding force of the air is less in proportion upon the larger shot, yet, owing to its slower progressive movement at the corresponding points of its flight, the comparative velocity of rotation required would be greater; therefore, although a great progressive velocity in the shot requires a greater velocity of rotation, a low velocity of flight will require an equally great *turn;* and this would not admit of its being decreased in a greater proportion than is given above.

In carrying out this principle, however, there is a circumstance which must not be lost sight of, namely, that the angle of the turn becomes less as the calibre of the gun increases. It would be necessary to consider this in calculating the capabilities of large guns, as, unless the charge of powder be increased in some measure, their ranges, when compared with those of

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would not be so noticeable; but these shot, when fired at great elevations, should have a much lower initial velocity than the above given to them; otherwise, in order to keep them perfectly steady and true *throughout* their flight, they would require a velocity of rotation which could not be given to them by means of the grooves without the risk of stripping. It is therefore scarcely possible (even were it expedient) to give a *very* high velocity to rifle shot, except by the employment of a very slight turn, and a consequent sacrifice of accuracy at any but comparatively limited distances.

smaller guns, will be rather less in proportion to their size.

Now, in order to ascertain the proper turn for a gun of any given size, it will be necessary, in the first instance, to have recourse to a correct standard. This can only be ascertained by experiment, as it will depend upon the shape and size of the shot to be used. In making the necessary experiments, it is advisable to use a gun having as nearly as possible the same proportionate length of bore as that of the larger guns to be employed for the same kind of shot or shell, otherwise there are a variety of circumstances to allow for (such as the friction), which are rather difficult to calculate.

The turn which I shall take to illustrate the method by which I propose to apply the principle to large guns is one which, after many trials, I found to answer best for the shell of which I have given a description in another place. This turn is about 64 inches in length for a gun having a bore of 1·2 inches in diameter.

We will suppose therefore that it is required to find the relative length of turn for a gun with a bore 4·2 inches in diameter, which is the size of the bore of a gun now being constructed upon these principles. It has been shewn that the turn should be diminished rather more than two-fifths for a gun having a bore of twice the diameter of another. The quickest way of ascertaining this, where the calibre of the gun for which the turn is required is more than double that of the other, is by an empirical method, which gives

the right length within an inch or two, and therefore nearly enough for all practical purposes. It may be done thus: divide the larger diameter by the smaller, extract the square root of the quotient, and multiply the quantity thus obtained by the length of the turn.

Therefore, in order to find the length of turn required for a gun with a calibre 4·2 inches in diameter, which is to be used for firing a similar shot or shell as another with a bore 1·2 inches in diameter, for which the proper length of turn has already been ascertained to be 64 inches, we must multiply 64 by 1·87, this being the square root of 3·5, the number of times that 4·2 (the diameter of the larger bore) contains 1·2 (the diameter of the smaller); the product will be 119·68 inches, or ten feet all but a fraction.

This then will be the proper length of turn for a gun having a bore of 4·2 inches in diameter, destined for the employment of that particular kind of projectile for which a turn of 64 inches in length has been ascertained to be the best, when propelled from a gun with a bore 1·2 inches in diameter; and the proper turn for guns of any other calibre may be found in a similar manner, the correct length of turn for the shot or shells to be used with them being previously ascertained on a smaller or larger scale.

I think no one will deny that the less turn (provided it be sufficient) the better; and my chief endeavour has been not only to arrive at a correct method of applying the principle to large guns, but also to discover the

minimum quantity of turn sufficient for all purposes. As it is absolutely necessary, however, that the rotation of the shot about its axis should continue in an effective manner throughout its flight, (in all cases at least, where great elevations may be employed,) it is better to have rather too much than too little.

In a small work of this kind it is impossible to enter more minutely into the investigation of a subject on which so much might be said; all I have attempted is to give a general outline of the method which appears to me to be the correct one of applying the principle of the rifle to cannon, and I will conclude by briefly summing up the principal points in it which I consider worthy of attention.

First, then, as a general rule, we find that the length of the turn of the rifling can be decreased in guns of larger calibre than others, only in proportion to the relative increase of the weight of the shot employed above that of their surface, or the resistance of the air, consequent upon their larger size, which is in a ratio of rather more than two-fifths for a gun with a bore of twice the diameter of another.

In the second place, we find that, accordingly, the turn will be greater in proportion to the size of the gun as the diameter of the bore increases, thereby causing it to have a sharper angle in large guns, in a ratio about as the square roots of their calibres; and in consequence of the initial velocity of all shot fired with similar charges remaining the same, the velocity

of rotation communicated to the shot by the greater comparative turn will be made at the expense of its velocity of flight and range.

Thirdly,—That it is the weight and form of the projectile which have in the first instance the chief influence on the turn, and therefore it is incumbent to make use of that form which would require the least, as it is of importance to avoid, as much as possible, diminishing the angle, in proportion as the size of the gun is increased.

The shot which require the least turn are, first, those of the most perfect concentricity, and of which the surfaces offer the least resistance to the air, as their rotary motion suffers less impediment; secondly, those which have their centre of gravity in their fore part, as their stability is greater, and consequently they require less turn to keep them true; thirdly, those of which the form approaches more nearly to a cylinder, as in them the accumulated work (due to the rotation) is greater than in any other form of shot of the same diameter and length, and they consequently require a less turn than is the case when they are made in the form of a lengthened cone;* fourthly,

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* The following will further illustrate this point. Let a be the length, and b the diameter of each of two shots, one of which is a cylinder and the other a cone, and let these shots be projected from a cannon with the same *angular velocity* (or velocity of rotation). By certain mathematical operations (into which the integral

those which have the greatest density,—thus a leaden bullet will require less turn than an iron one, for the work accumulated in producing the same angular velocity in the two will be greater in the lead than in the iron one, while the forces opposed to the rotation of the two are (or may be supposed to be) the same. The less prominent the foregoing qualities appear in shot the greater will be the turn required for them, although some have a greater influence upon the turn than others.

In applying the principle of the rifle to cannon, it appears, that in using even the smallest effective turn

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calculus enters) the moment of inertia (I, suppose,) of the cylinder is easily ascertained to be given by the equation

$$I = \tfrac{1}{2}\, b\, a^4;$$

and the moment of inertia (I_1, suppose,) of the cone is similarly found to be given by the equation

$$I_1 = \tfrac{1}{10}\, b\, a^4;$$

from which two equations it will at once be seen that

$$I_1 = \frac{I}{5}$$

or that the moment of inertia of the cylinder is five times that of the cone. Now the *work* accumulated in each in generating the given velocity, is found by multiplying I and I_1 respectively by a constant quantity; from which it follows that the *work* accumulated in the cylinder is also five times that accumulated in the cone. But the resistance and friction of the air, by which alone the work is in each case to be destroyed, are certainly not five times greater in the one case than in the other; whence we may conclude with certainty that the angular velocity of the cylinder may be reduced to less than that of the cone.

for the most favourably formed shot, the smallness of its angle will give a limit to the length of the gun. In fact, the turn required for a gun with a bore of from twelve inches upwards would be so great in proportion to its size, that it would be necessary to reduce the length of the bore in proportion to the decrease in the angle of the turn, which would in extreme cases reduce it almost to the dimensions of a mortar, in order to avoid the recoil, friction, &c., which would be occasioned by the sharp angle of the turn, in firing the ordinary charge of powder, were the gun of a proportionate length.

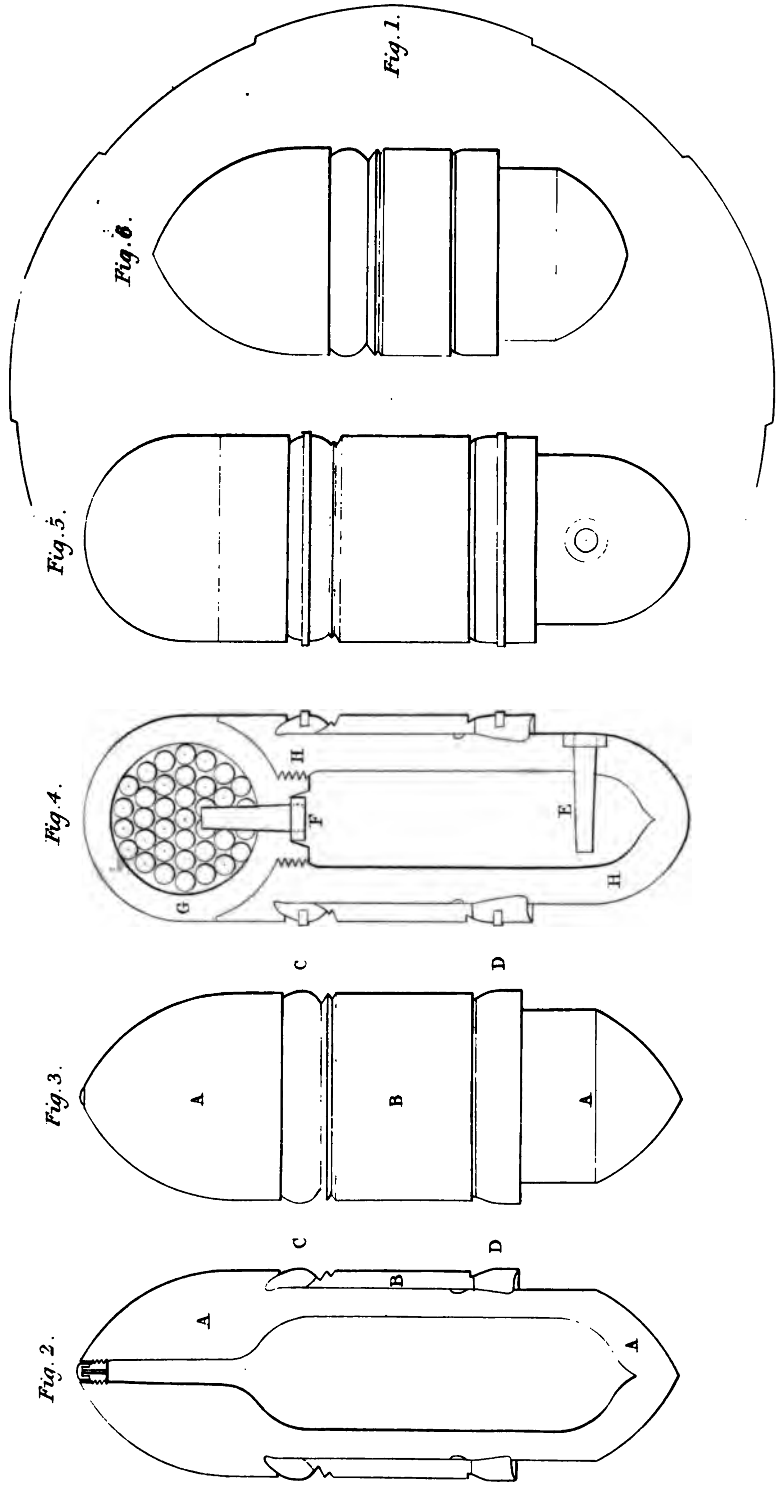
All these circumstances tend to shew how important it is to acquire in the first instance a knowledge of the due length of turn required to keep the projectile true during its whole flight, for it is only by availing ourselves of this knowledge that the greatest effect is to be obtained with rifled ordnance, since (when fired with equal velocities) too great a turn will cause a diminished range, and too little a want of accuracy.

With regard to the grooves, I think it is generally admitted that the fewer they are in number the less is the friction, and I should certainly advocate the use of only three were the angle of the turn the same as in an ordinary rifle; but as this is not the case, and as that portion of the shot which enters the groove is, in the case of cannon shot, smaller in proportion to its size than when the whole projectile is

formed of lead, I think it preferable to use five. In the gun which is now being made for me, and which is represented in the frontispiece, there are to be five grooves, rather broader than the bearings, and one-thirty-second part of an inch in depth, but going off about one-sixty-fourth part of an inch deeper towards the centre, and having the edges slightly inclined inwards, as shown full size in Fig. 1, Plate I.

I have not considered it necessary to notice the principle of the increasing spiral, which is chiefly used by the Americans, as it would not be suitable to shot such as I propose should be employed. As to any advantage attending it, it appears to be entirely a question of the friction of the shot's passage out of the gun, as it must ultimately acquire a velocity of rotation corresponding to the last turn given to it before quitting the piece.

Plate 1



J.W. Lowry fc.

OF THE PROJECTILE.

Assuming that the principles laid down in the preceding pages are correct, it remains to determine the best principle to be followed in the construction of the projectile, in order to profit by the advantages of rifled ordnance to the greatest possible extent. The difficulty of obtaining a shot or shell combining all the necessary qualifications, has hitherto proved one of the main impediments to the more extended use of guns of this description. Let us, therefore, enquire into the nature of the required combination of qualities, and ascertain of what it really consists.

1st.—It is indispensable for a shot to be of a certain density or specific gravity, in order that a proper degree of range may be obtained with it.

2ndly.—Its axis should coincide perfectly with the axis of the bore before leaving the gun, and, therefore, it must completely *fill* the bore, otherwise its flight can never be depended upon; hence the fatal objection to homogeneous shot of a non-expanding metal.

3rdly.—Its centre of gravity should be thrown forward before its centre of figure, in order to give it more stability, and less inclination to turn over. This

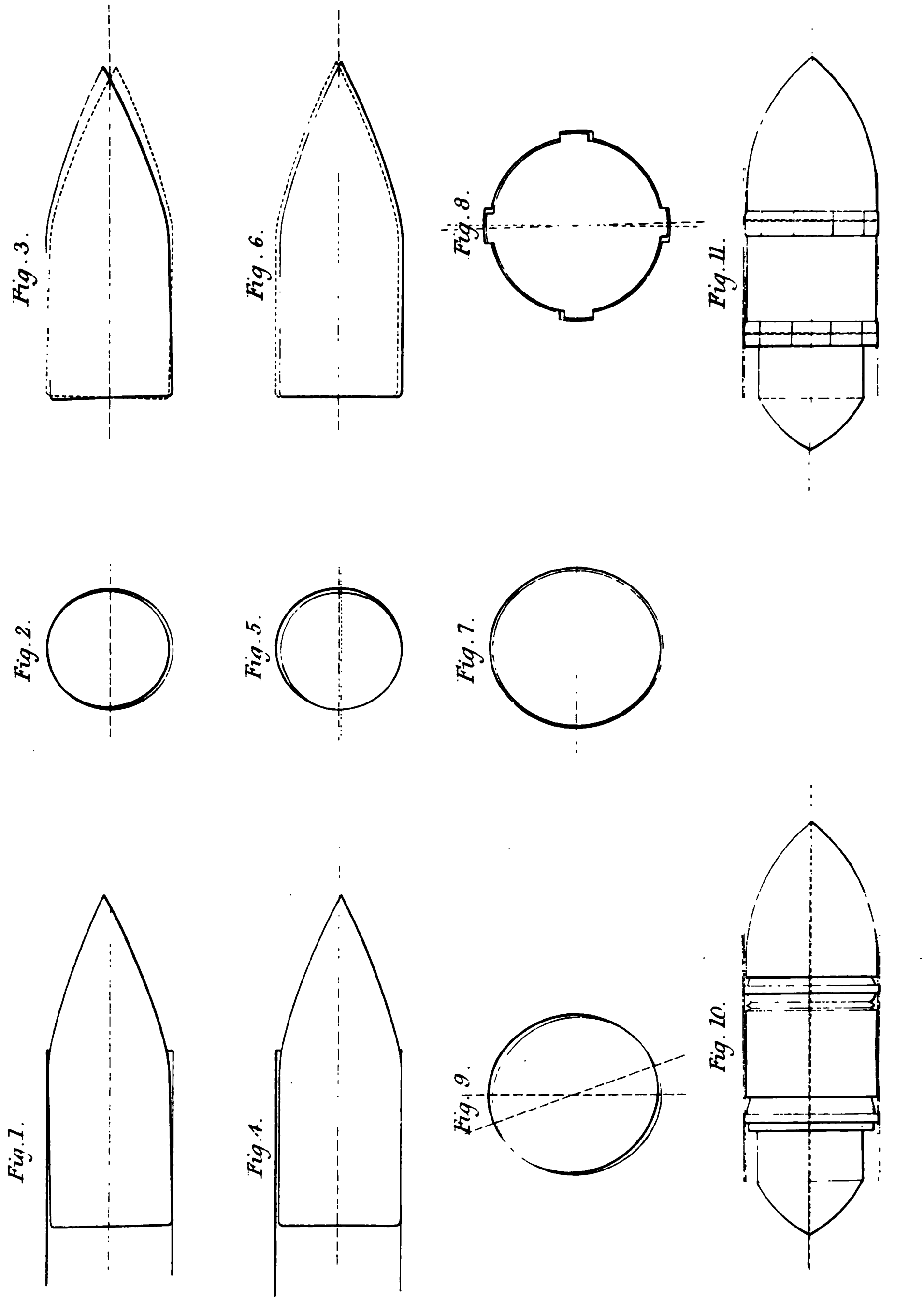
will allow of the use of a less turn in the rifling, which is an important object in guns of large calibre. There are also other reasons for it, which I shall describe more fully hereafter.

4thly.—Assuming the necessity of employing a compound shot or shell, an even expansion of that portion of the shot which is to take the grooves is absolutely necessary; for unless the axis of the shot be made to coincide exactly with the axis of the bore immediately upon its receiving the impulse from the powder, the chief advantages attending the expansion will be completely neutralized.

Lastly.—It should be of a form offering as little resistance to the air as possible.

These appear to be the chief requisites for projectiles generally, which are to be used with rifled cannon. It would be preposterous to deny the advantages of homogeneous shot; but they are wanting in one of the above qualifications, and this unfortunately is the most important with rifled guns; for it would be impossible to obtain any very great degree of accuracy (which in fact ought to be one of the chief advantages gained by the employment of rifled cannon), where this property (that of completely filling the bore) is wanting in a shot. Sufficient windage must always be allowed for the fouling of the bore, and its contraction when heated, even in breech-loading guns; and this being the case, a round shot can only come in contact with the interior of the

Plate 2.



J.W. Lowry sc.

gun at one point, and an elongated shot at only two points (or along a line) at the same time,* and, therefore, the latter can only have its axis coincident with the axis of the bore (which, it must be remembered, is also that of its line of flight) when it is in such a position as either not to touch the gun at all, as in Fig. 7, Plate II., or to bear upon the grooves only, as in Fig. 8, Plate II., positions which may be accidentally assumed by the shot, but which it cannot be compelled to assume; † no patch or wadding will remedy this defect.

There is also a circumstance attending the flight of shot, when fired from rifled guns, which requires more particularly to be noticed where elongated projectiles are used, viz., when the centre of gravity in the shot is at, or behind, the centre of its figure, the axis very soon ceases to coincide with the axis of its trajectory,‡ and not only causes the deflection of the

* I have endeavoured to represent some of the different positions of the shot, both before and after leaving the bore, in Figs. 1 to 6, Plate II.

† Fig. 9, Plate II., represents the same conditions in an elliptically bored gun, as Fig. 8 represents in a grooved gun.

‡ Robins notices this in his remarks upon the rifle, where he says, "that though the bullet impelled from them (rifles) keeps for a time to the regular track with sufficient nicety, yet if its flight be so far extended that its track is much incurvated, it will then often undergo considerable deflections. This, according to my

shot, but where percussion shells, for instance, are used, prevents them, when fired at great elevations, from falling point foremost upon the object aimed at.*

Robins proposed a remedy for this in his egg-shaped bullet; but from the remarks of the Author of "Scloppetaria," it appears that it met with indifferent success, and that its flight varied very much; he also observes that unlike other shot it always flew to windward. In the Pritchett bullet (which possesses

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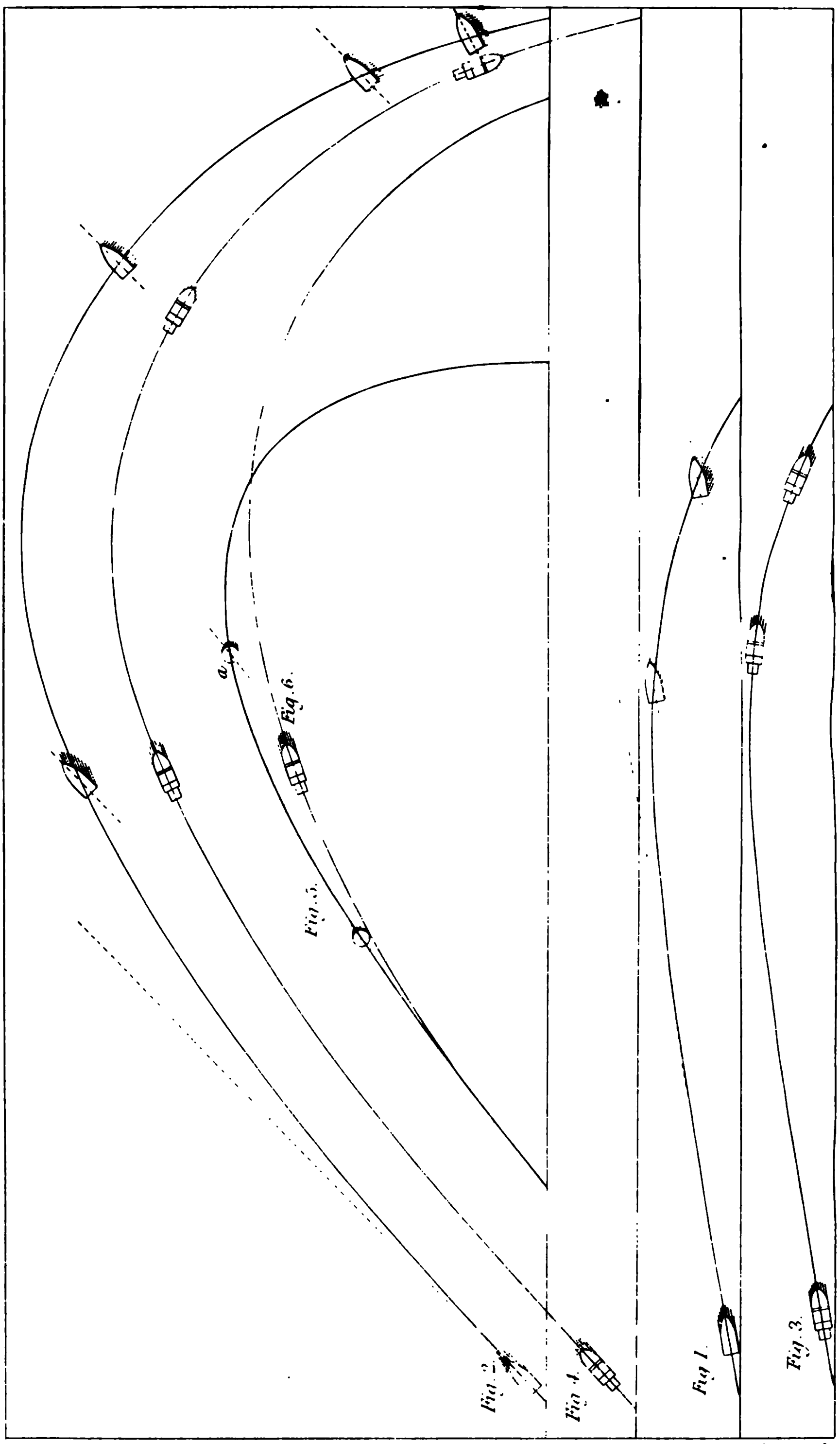
experiments, arises from the angle at last made by the axis upon which the bullet turns, and the direction in which it flies; for that axis continuing nearly parallel to itself, it must necessarily diverge from the line of flight of the bullet, when that line is bent from its original direction, and when it once happens that the bullet whirls on an axis which no longer coincides with the line of its flight, then the unequal resistance described in the former papers will take place, and the deflecting power hence arising, will perpetually increase as the track of the bullet, by having its range extended, becomes more and more incurvated." See *a* Fig. 5, Plate III.

* Those who contend that the longer axis of a shot will continually coincide with the axis of its line of flight, and descend point foremost, when its centre of gravity is *not* before its centre of figure, (no other means being employed to increase the retarding fore of the air upon its hinder part,) must also be prepared to maintain that the rotary motion given to a shot will cause the usual effects produced by the action of gravitation upon a body projected in the air, to be in such case suspended, or rather, if I may so speak, to be reversed, by bringing the lighter part of the shot to the ground first; which would be as much at variance with the existing theory of the air's resistance, as with all the known laws relating to Dynamics.

Plate 3.

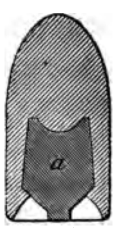


J W Lowry sc

the advantages without the defects of the egg-shaped bullet) this imperfection is remedied in some degree, but scarcely sufficiently to give proper effect to shot, when fired at great elevations.*

In Plate III., I have given representations of the positions of several shot as they would appear during their flight. Fig. 1 represents the positions, at the several points of its flight, of a shot having its centre of gravity at or behind the centre of its figure. Fig. 2 shews the same shot fired at a greater angle of elevation; the more extended its range the greater will be the deflection arising from this circumstance; the main pressure of the air being upon the whole of the lower surface of the shot, will also cause the flight of long shot to suffer considerable reduction, if the centre of gravity be not sufficiently forward to keep their axes coincident with their trajectories.

* The accompanying diagram gives a sectional view of a bullet, (*a*, being a plug of tin, zinc, antimony, or other lighter material, to be placed in the bullet when cast,) which appears to me of a description somewhat better calculated to produce the desired effect; although, on on account of the extra trouble and expense attending the manufacture, it might probably be inexpedient to use such for military purposes. Beside having its centre of gravity thrown more forward than is the case with the Pritchett bullet, this would, moreover, have the advantage of possessing in itself that property of expansion which with others is commonly obtained by the uncertain method of a detached cup or plug.



When to this is added the irregularity in the flight of homogeneous shot, resulting from the causes represented in Plate II., it is not much to be wondered at, that little dependence is to be placed upon them. Figs. 3 and 4 represent the positions in its flight of a shot having its centre of gravity sufficiently forward to enable it to keep the longer axis coincident with the line of flight throughout its extreme range. This is a much more important consideration where percussion shells are to be employed on a large scale and at great elevations, than with small arms, where the elevations used are comparatively trifling, in consequence of which attention has not hitherto been much attracted to the matter.

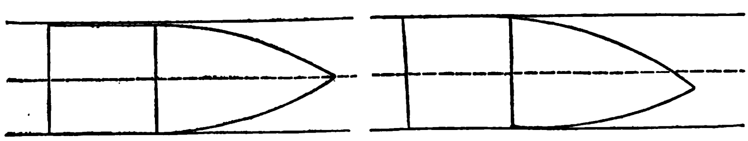
The nature of the advantages to be derived from the employment of elongated projectiles is much more in favour of the use of shells than of solid shot; for although the mean velocity of the flight of elongated shot is the greater, yet the much higher initial velocity with which round shot can be fired will always cause the latter to prove more effective at short ranges. The main advantage attending the use of rifled cannon is the power of projecting a very heavy shell, without increasing the weight of the gun materially; and to carry this out to its greatest extent very little regard must be paid to velocity. To attempt to give to any kind of elongated shot an initial velocity at all approaching that with which spherical shot are fired (putting aside the impractica-

bility of it on other grounds) would entail the employment of very heavy guns, and thus the advantages to be gained by their use would be half destroyed, and the extended ranges obtained with guns of the same weight of metal would not even then exceed those of the heavier shot fired with lower velocities. The principle to be adopted with this kind of projectile, in order to obtain the full advantage arising from their use, is clearly that of throwing as heavy a shell as possible without employing a greater weight of metal in the gun.

After repeated experiments, (which occupied me some months,) made for the purpose of obtaining a shell in which should be combined all the necessary qualifications in a manner adapted for practical use, I arrived at the form of shell shown in Plate I., Figs. 2 and 3, which in this instance is three diameters long, but may be altered to any length, greater or less. Fig. 2 is a longitudinal section, and Fig. 3 an external view. A is the body of the shell (of cast iron); B an iron ferrule or ring, which is sufficiently loose to be moved up or down the body of the shell with facility. C is a ring of lead cast on to the shell, and dovetailed on the body in two or three places. D is another ring of lead, or other suitable metal, also cast on to the body of the shell. The hinder part of the shell is formed in the manner shewn in the engraving, with the view of throwing the centre of gravity as far forward as possible, as well as to allow of the use of a

fuse; I had also other reasons for making it of this form, which would take up too much space to explain fully, as they are connected with a variety of experiments which I have made.

The principal feature in this shell is the ferrule or iron ring, the purpose of which I will explain. In making experiments with shot more than two diameters in length, I found a difficulty in procuring with them an expansion sufficiently even to cause their axis to coincide with the axis of the bore of the gun, unless by adopting means unsuitable for practical purposes. The first of the accompanying diagrams represents the position of such a shot with an expanding ring upon the hinder end only, before the discharge; and the second represents the position which the same shot frequently assumes after the discharge.



After many attempts, I at length succeeded in effecting the above object by means of the ferrule, B, which acts in the following manner. Upon the explosion of the powder, the lower ring, D, is caused to expand and fill the grooves, and at the same moment is driven, together with the iron ring, B, in a forward direction; the latter acting as a wedge upon the top

ring, C, causes it to expand sufficiently to fill the bore, thereby occasioning a simultaneous expansion at two points. The first effect therefore of the explosion of the powder upon the shot is to force its axis to coincide with the axis of the bore; it then drives it out in a perfectly straight direction. The freedom of expansion allowed to the powder by the formation of the hind part of the shell permits the first action to be accomplished before the whole body of the shell is sensibly moved from its place. Figs. 10 and 11, Plate II., represent the shell as it lies in the bore, before and after the discharge.

There is no difficulty attending the loading with this shell, and no wadding is required. The expansion, taking place at two points, allows of the use of a much less quantity of lead than would otherwise be the case with shot or shells of their proportions, and, consequently, the friction in the gun is considerably diminished. There is also no difficulty attending the manufacture of the shell, though that is a point which should not be so much considered as the simplicity in its use. There are several minor points connected with it, which it is not necessary to notice here, my object being merely to give a general idea of the principles of its construction.

Figs. 4 and 5, Plate I., represent a longitudinal section, and an external view, respectively, of a double shell. It is similar in form to the one just described; the principle of its construction being in

every respect the same, except that instead of being a percussion shell it is fired with a fuse, E, by means of which (after passing over a certain distance) the hind part, H, is blown to pieces, at the same time freeing the top part, G, and lighting the fuse, F. The top part, or round shell, G, continues its flight according to the length of the fuse, when a second explosion takes place. This shell would doubtless prove very destructive, when used against large bodies of troops.

Fig. 6, Plate I., is an external view of a shell similar to that shown in Figs. 2 and 3, showing how the size may be reduced.

I think it will be found that these shells combine all the qualities set forth as requisite. There may be other and better mechanical means of accomplishing this; but after numerous experiments, it is the only method by which I have been able to unite all the qualifications necessary for an elongated shell, where its length is not very limited.*

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* I wish it to be understood in this, as in all other parts of this work, where a description of any particular kind of projectile or mechanical contrivance is given, that I have simply chosen those for description which were found to answer the best (amongst many others) in my own experiments; and with the view, rather of illustrating certain principles, and at least one method of carrying them into practice, than of recommending any individual shot or shell, of the identical *form* represented (which, provided the same conditions are observed, may be modified to any suitable extent), for adoption; for I am fully aware that many things of this nature (although giving excellent results in experiments) frequently

The effect produced by these shells is very great, and employed against shipping they would prove extremely destructive. A gun of the same weight as a 24-pr. howitzer, mounted in a ship's boat instead of it, would in most instances possess great advantages over it.

The track described by the flight of elongated projectiles, in consequence of their weight being so much greater compared with the surface which they oppose to the resistance of the air, than is the case with spherical shot, must approach more nearly to the curve of a parabola than the track described by the latter.* This will admit of their being used with a

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require to undergo considerable modifications, before they can be rendered in every respect fit for actual service. The true principles, however, of an art or science being once understood, and the effect produced by certain combinations clearly ascertained, the discovery of the most suitable mechanical means to be employed in carrying them out, will soon follow.

* Figs. 5 and 6, Plate III., are intended to give an illustration of the flights of a round and an elongated shot respectively, more, however, as a representation of the different description of curve described by the two kinds of shot, than of their relative ranges. The round shot is supposed to be fired with the ordinary, and the long shot with a lower velocity. I should also remark that the curves described by Figs. 1, 2, 3, and 4, are represented as being the same in each case, whereas they would in fact differ very nearly as much as those represented in Figs. 5 and 6; but as they are only intended to draw the reader's attention to the effects produced by an alteration of the position of the centre of gravity in the shot, I did not consider it necessary to attempt to define the relative

for I have found it to be equally the case when their centres of gravity were placed as forward (in proportion) in the longer as in the shorter shot, otherwise this might naturally be supposed to be the cause of it. I made frequent experiments with shot, ranging from one and a half to between four and five of their diameters in length, in order to ascertain if this were really so, and also the cause of it, and I invariably found that the greater the length of the shot, the less was the initial velocity which could be imparted to it. This is a circumstance which must be attributed solely to the different effects of the resistance of the air upon this particular kind of shot; for were the same portion (or fore part) only of the long shot influenced by the pressure of the air, or did the latter promote its rotary motion in any way, they could be fired with a velocity not only equal but superior to that of spherical shot, in a proportion according to their additional weight, provided they had sufficient stability, or turn enough to keep them straight.

I found, however, that this was not the case, for it clearly appeared that, although by increasing their length (to a certain degree), a greater extreme range could be obtained, yet the velocity with which they were fired had to be reduced in proportion; and also that by increasing their length beyond a certain point, the velocity which they would then bear was so small as to be insufficient for them to acquire momentum enough to give them a proper range, so that by

increasing their length beyond this point no advantage was to be gained, but the contrary.

There can be no doubt that the shot, of whatever length it may be, is propelled during its passage through the bore of the gun with a velocity according to the charge of powder with which it is fired; whatever therefore subsequently affects its flight, must be occasioned entirely by the action of the air; and the reason why the flight of these shot is affected by it in so peculiar a manner, must arise from their elongated form and rotary motion combined.

The retarding force of the air acts upon them in a twofold manner: in the first place, upon their fore part, tending more immediately to retard their direct flight; and secondly, by its increased pressure upon their longitudinal surface, tending to check their rotary motion; and therefore the peculiar effect of the air upon them may be accounted for in some measure by the fact that any additional increase in the length of these shot, although adding to their momentum generally, without any corresponding increase of the resistance of the air on their fore end, yet adds little to the momentum or impetus of their rotary motion, whilst it increases their longitudinal surface in a much greater proportion, so that when fired with the same velocities as the shorter, their rotary motion is checked in a greater degree by the pressure of the air; the mean velocity of their flight being greater, this pressure is also continued for a much longer time; and

greater degree of accuracy at long ranges, and allow of a gun being used with more than usual effect (in throwing shells) at very great elevations. But with gun carriages for land service, as at present constructed, a greater elevation than sixteen or eighteen degrees could not conveniently be obtained. In order to remedy this, I would suggest that a joint be made in the trail, similar to that represented in the frontispiece, so that by means of an endless screw the gun may be elevated or lowered. I have already applied this method to a gun carriage, on which a 28 cwt. gun was mounted, and it appeared to stand the effects of the recoil very well. The dotted figure in the plate represents the highest elevation attainable with the ordinary gun carriage; the other figure represents the gun at an elevation of 45°, as effected by means of the joint in the trail. The smaller figure of the frontispiece is a sectional view of the joint, showing the manner in which it works. No elevating screw need be employed at all with this joint; and if it were thought expedient, trunnions might also be dispensed with.*

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curves described by each: the different surface which is offered by them to the resistance of the air, and consequently the difference in the amount of retardation suffered by each, will convey to the mind of the reader some idea of what these should be.

* See the figure upon the cover of the book, representing a rifled howitzer and carriage, constructed in the above manner.

GENERAL REMARKS.

Before concluding this subject, there are one or two points in connection with the employment of guns, constructed as described in the preceding pages, which require to be noticed, and deserve especial attention when determining the best method to be adopted in order to profit as much as possible by the peculiar advantages attending their use. At the same time, I have a few remarks to offer respecting the causes and effects of the rotary motion of shot generally.

Opinions, I believe, still differ as to whether the rotary motion of the shot is given to it by the grooves alone in its passage through the bore of the gun, or whether they merely give it its first impulse, the motion being continued during its flight by the action of the air upon the projections (caused by the grooves) upon the shot's surface.

Notwithstanding that some persons (whose opinions on such matters possess a certain value) have maintained the latter to be the case, I think that experiments made with elongated shot will give ample proof that the former is decidedly the correct notion, and that the rotary motion given to the shot is caused solely by the twist which it receives in passing through

for I have found it to be equally the case when their centres of gravity were placed as forward (in proportion) in the longer as in the shorter shot, otherwise this might naturally be supposed to be the cause of it. I made frequent experiments with shot, ranging from one and a half to between four and five of their diameters in length, in order to ascertain if this were really so, and also the cause of it, and I invariably found that the greater the length of the shot, the less was the initial velocity which could be imparted to it. This is a circumstance which must be attributed solely to the different effects of the resistance of the air upon this particular kind of shot; for were the same portion (or fore part) only of the long shot influenced by the pressure of the air, or did the latter promote its rotary motion in any way, they could be fired with a velocity not only equal but superior to that of spherical shot, in a proportion according to their additional weight, provided they had sufficient stability, or turn enough to keep them straight.

I found, however, that this was not the case, for it clearly appeared that, although by increasing their length (to a certain degree), a greater extreme range could be obtained, yet the velocity with which they were fired had to be reduced in proportion; and also that by increasing their length beyond a certain point, the velocity which they would then bear was so small as to be insufficient for them to acquire momentum enough to give them a proper range, so that by

addition to a true flight, they may acquire the property of stability which the arrow possesses previously to its discharge. This can only be obtained, either by giving them a certain degree of length (in proportion to the diameter) behind their centre of gravity, or by giving them a violent rotary motion.

It is true, that by constructing a compound shot of iron and some lighter material, in such a manner that its centre of gravity may be thrown forward considerably, and by supplying it with projections, or some substitute corresponding to the feathers in an arrow, it may be made to approximate more nearly to the condition of the latter; and in such a case, a certain analogy may appear to exist between them; but its tendency to oscillate would be infinitely greater, both from its deficiency in length, and its superior density, which would cause it to have a greater rapidity of descent; that is to say, it would fall a greater distance in the same space of time, and consequently the resistance of the air would act upon it in a more oblique direction; and it would, under these circumstances, of course require a much greater velocity of rotation than the arrow. As this description of projectile would not therefore possess sufficient stability to counteract the resistance of the air upon its fore part, encountered upon leaving the gun, it would immediately upset, and if it did not turn over, would oscillate and acquire no rotary motion whatever, for the air will only promote a rotary motion

where almost perfect stability exists; and in a shot of this kind, fired from a smooth bore gun, this stability could only be given by means of a pressure of the air upon its hinder part, equal or superior to that which it receives upon its fore end, or by some means equivalent in effect to that portion of the shaft of an arrow which is behind its centre of gravity. An opposing surface sufficient for this purpose, could not be given to a projectile of which the diameter is limited, except by giving it the length of an arrow, or making it all wings, which would effectually check its flight. In fact, however ingenious many of these and other inventions connected with projectiles may be, unless the full power of ordinary shot, either with regard to velocity or range, can be obtained with them; they are practically useless.

Elongated shot, when fired from a *rifle*, have the deficiencies of those above-mentioned made good by having the rotary motion imparted to them in the first instance. This gives them a proper degree of stability, and allows of their being fired with a sufficient velocity to enable them to be used with great effect; and even if fired with tolerably high velocities, the velocity of their rotation, being in proportion to that given to their flight, is sufficient to counteract the resistance of the air upon their fore part; but if fired with more than a certain velocity, *they* also will upset, but from a different cause, which I will explain presently. Those who imagine that the rotation of

the shot is caused by the action of the air in its passage through it, do not apparently consider that the shot makes at least fifty or sixty revolutions about its axis during the *first second* of its flight. There might have been some grounds for the opinion formerly, when rifles with deep cut grooves were used; but to suppose it possible that such an effect could be produced by the action of the air upon such a bullet as that fired from the Enfield rifle, for instance, upon which the projections caused by the grooves are scarcely perceptible, seems altogether absurd. If the air *promoted* the rotary motion in the shot, its effect in that way would be more apparent upon elongated, than upon spherical shot of the same diameter, as would also its action in *checking* their rotary motion (supposing it to have that effect); but as experiment shews the latter to be the case, I think we may fairly conclude that the question is settled.

This brings me to one of those points which I alluded to, as deserving particular mention; and this is the remarkable circumstance attending the projection of elongated shot, that (contrary to the rule with round shot) not only is their range diminished, when fired with more than a certain velocity, but that the greater their length, the less is the velocity with which they can be propelled.

This does not arise (as at first one might be inclined to suppose) from a want of stability in the shot,

for I have found it to be equally the case when their centres of gravity were placed as forward (in proportion) in the longer as in the shorter shot, otherwise this might naturally be supposed to be the cause of it. I made frequent experiments with shot, ranging from one and a half to between four and five of their diameters in length, in order to ascertain if this were really so, and also the cause of it, and I invariably found that the greater the length of the shot, the less was the initial velocity which could be imparted to it. This is a circumstance which must be attributed solely to the different effects of the resistance of the air upon this particular kind of shot; for were the same portion (or fore part) only of the long shot influenced by the pressure of the air, or did the latter promote its rotary motion in any way, they could be fired with a velocity not only equal but superior to that of spherical shot, in a proportion according to their additional weight, provided they had sufficient stability, or turn enough to keep them straight.

I found, however, that this was not the case, for it clearly appeared that, although by increasing their length (to a certain degree), a greater extreme range could be obtained, yet the velocity with which they were fired had to be reduced in proportion; and also that by increasing their length beyond a certain point, the velocity which they would then bear was so small as to be insufficient for them to acquire momentum enough to give them a proper range, so that by

increasing their length beyond this point no advantage was to be gained, but the contrary.

There can be no doubt that the shot, of whatever length it may be, is propelled during its passage through the bore of the gun with a velocity according to the charge of powder with which it is fired; whatever therefore subsequently affects its flight, must be occasioned entirely by the action of the air; and the reason why the flight of these shot is affected by it in so peculiar a manner, must arise from their elongated form and rotary motion combined.

The retarding force of the air acts upon them in a twofold manner: in the first place, upon their fore part, tending more immediately to retard their direct flight; and secondly, by its increased pressure upon their longitudinal surface, tending to check their rotary motion; and therefore the peculiar effect of the air upon them may be accounted for in some measure by the fact that any additional increase in the length of these shot, although adding to their momentum generally, without any corresponding increase of the resistance of the air on their fore end, yet adds little to the momentum or impetus of their rotary motion, whilst it increases their longitudinal surface in a much greater proportion, so that when fired with the same velocities as the shorter, their rotary motion is checked in a greater degree by the pressure of the air; the mean velocity of their flight being greater, this pressure is also continued for a much longer time; and

although the action of the air upon their longitudinal surface is experienced but slightly when fired with moderate velocities, as is proved by the ordinary ranges of rifles compared with those of smooth bore guns, it becomes more apparent as they are increased, and very much more so when the length of the shot is increased as well, so that with the same turn of the grooves, the longer the shot the less velocity it will bear. If in order to meet this the turn were increased, it would (for shot over a certain length) require a velocity of rotation, which it would be impossible to give to it, without either an enormous sacrifice of range, or the risk of the shot stripping; and therefore the means which it would be necessary to employ to prevent this effect, would completely nullify the advantage derived from the increase in its length.

It is evident, therefore, that the longer the shot the greater will be the retarding force of the air upon its rotary motion; so that upon increasing its length, its velocity must be decreased in proportion to the increase in its surface in a longitudinal direction, otherwise the additional impetus of its motion about its axis, not being sufficient to counteract the greater retarding power of the air caused by the increase in its surface, its rotary motion will be destroyed, or, at least, rendered totally inefficient, and consequently its axis will no longer coincide with the line of its flight; and, the pressure upon its fore end being in an oblique direction, it will either turn over completely,

or acquire an oscillating motion, according to the position in it of its centre of gravity; so that instead of presenting a less surface to the resistance of the air than that of a spherical shot of the same weight, it may offer a greater, and its range will be diminished accordingly. The higher therefore the velocity with which it is fired, the more speedily will its rotary motion be lost, and the longer the shot the sooner this effect will be produced, in a proportion depending upon the increase in its longitudinal surface. And although a corresponding increase in the velocity of its rotation would in some measure counterbalance this, yet, as the least additional velocity is followed by such an enormous increase in the retarding power of the air upon its rotary motion, it would, for it to have the necessary velocity of rotation, require a turn of the grooves which it would be impossible to employ with any but the lowest projectile velocities.

This renders it apparent that the length of shot or shell must necessarily be limited, and that the greatest effective length for a shot (for range) will therefore be that, which will just enable it to bear a velocity sufficiently high to give it momentum enough to attain the greatest range possible, without causing so great a pressure as to check injuriously its rotary motion.

This greatest effective length appeared to me (from experiments) to be about three times its diameter, when shot with their centre of gravity thrown forward to a certain degree were used (similar to those

shown in the engraving, Plate I., Figs. 1 and 2), although with others of a spherico-cylindrical form, the greatest length that could be used with advantage was about $2\frac{1}{8}$ times its diameter; and every increase in the length of all these shot was followed by a diminished effect, by reason of the impracticability of giving them sufficient momentum on account of the low velocities, as well as of the great twist which it became necessary to employ with them. Upon reducing their length, on the other hand, the effect again became less, as their momentum was then insufficient, owing to their deficiency in weight. This has reference to the *range* of the shot; their force of impact, however, will be increased by reducing their length, upon increasing the proximity of the gun to the object to be struck, and at a distance of about fifty yards only from the muzzle of the gun, a round shot can be made to produce a greater effect than any other of the same diameter, of whatever form or length. This I have frequently proved by experiments. With large guns the distance would be considerably over fifty yards. This shews that the range of a shot is no criterion of its force of impact at short distances.

From the more rapid increase in the effect of the air upon the surfaces of these than upon round shot as their size is increased, will be seen the necessity of not diminishing the turn too much for shot of increased size. It is not so much the rapidity of the

shot's rotation which causes the action of the air to be so apparent upon it, as the larger portion of its surface which is affected by it, from its requiring any rotary motion whatever. For although the parts of elongated shot exposed to the main resistance of the air are in the same proportion to their diameters as the similar parts in spherical shot of different sizes, yet, owing to their greater longitudinal surface, the employment of an insufficient turn would, in their case, be accompanied by a more rapid diminution of the effect which would otherwise attend an increase in their size. From the above circumstances it also arises that the difference between the ranges of two differently sized shot of this kind, when fired with different velocities, does not vary so much as in the case of the two spherical shot instanced in a preceding part of this work; in fact their ranges are more uniformly determined by the relation between their weights and diameters, as, to produce the necessary effect with these shots, an almost invariable velocity must be given to them. For, owing to the rapid augmentation of the effect of the pressure of the air with any beyond a certain velocity it will be impossible to use any other than moderate velocities with them, and with these the effect of the air upon their longitudinal surface is not so perceptible; but directly the pressure arrives at a certain amount, it appears to neutralize the effect of the rotary motion altogether, and much less force is required to do this than to arrest the pro-

gressive movement, for the rotary impetus of the shot is slight compared with the translatory impetus, and a comparatively small impediment will check it. (This may be proved by firing a bullet through a board, when it will be seen, that although it will continue its onward flight, yet its rotary motion will frequently be completely destroyed by its momentary passage through the board, and it will be upset.) When extremely low charges are used, from the greater comparative turn and extra force expended in giving the larger shot its rotary motion, the differences again are not so great as between the ranges of two spherical shot of different sizes when fired from a smooth bore. Not having made any experiments with the ballistic pendulum, I am unable to state precisely the greatest velocity which can be given to elongated shot; but, judging by the ordinary rules for ascertaining the velocities of shot, as also from Hutton's Tables, I should say it would be somewhere between 700 and 800 feet in a second, varying according to the length of the shot. And when we consider that the ordinary velocity of a round shot is about 1800 feet a second, (and that even this can be considerably increased,) it will at once be perceived how much greater is the force of impact which may be produced with the latter at short distances than that which can be produced with the former.

By taking all the foregoing circumstances into consideration, we may weigh the advantages and

disadvantages arising from the employment of elongated projectiles. The former appear to consist, in the first place, of the power of throwing a heavy shot or shell to a longer distance, without materially increasing the weight of the gun, and also with greater precision; and, secondly, of the certainty of their explosion, when used as shells, upon striking the object. On the other hand, the disadvantages attending their use are, that in horizontal firing their effect is not so great as that produced by spherical shot, both on account of the comparatively low velocities which only can be given to them, and of their uncertainty in the ricochet; for I imagine, that in horizontal firing, the shot which would be the most effective for ordinary purposes, would be that which when fired at such an elevation as never to rise to a greater height than five or six feet from the ground, would do the most execution; and this, it appears to me, would be in favour of round shot, on account of their greater force of impact at short distances, as also because their direction when ricochetting is more to be depended on. Certainly by making use of an elongated shot of less length, its velocity might be made to approach more nearly to that of a round shot. But although their range is greater, yet, for the above reason, little advantage would attend their general use. Even as shells there would be no advantage gained by using them of a reduced length, for a heavier shell could be fired from a lighter gun by decreasing its diameter

and increasing its length, and with shells velocity would not be so much required as range; and if their make were such as not to admit their being used as Shrapnell shells, it would not do to use them with field pieces; the heavier shells could also be used with effect at much greater elevations. In fact, to obtain the full effect with these shells, they should be used with a particular kind of gun, and for particular purposes only.

As the principal advantages to be gained by their use lie in their extended range at great elevations, and in the greater precision with which they can be fired at these elevations, the purposes for which these qualities could be turned to the best account would be in the destruction of places or shipping, which could not otherwise be approached, and therefore it would be advisable to use *shells only*, and these could be propelled from a species of howitzer or mortar; and as, for the above reasons, they would be chiefly serviceable in naval warfare, they might be made to throw shells of very great weight, and to an enormous distance. But this, and all other questions as to the best mode of using them, is entirely for the consideration of competent military authorities.

Many points which I have noticed as deserving consideration may possibly appear trivial to those who have not paid much attention to the subject. But these trifles make in the aggregate the total effect of the projectile, and all who *have* studied

the subject, and followed it up by experiments themselves, must be well aware of the difference in the shooting of a rifled gun, which the most apparently trifling alteration will sometimes cause. There are few things which require so perfect a combination of qualities in order to attain to excellence as this, and nothing should be neglected which may tend in any way to ensure it; for although, when used as solid shot, the long may not be so effective for ordinary purposes as the round shot, yet, when employed as shells, they might almost supersede the latter, for either howitzers or mortars, and in all cases where velocity is not so much an object as a heavy shell and a true flight. The importance therefore of bringing the latter as near to perfection as possible, is scarcely to be over-estimated.

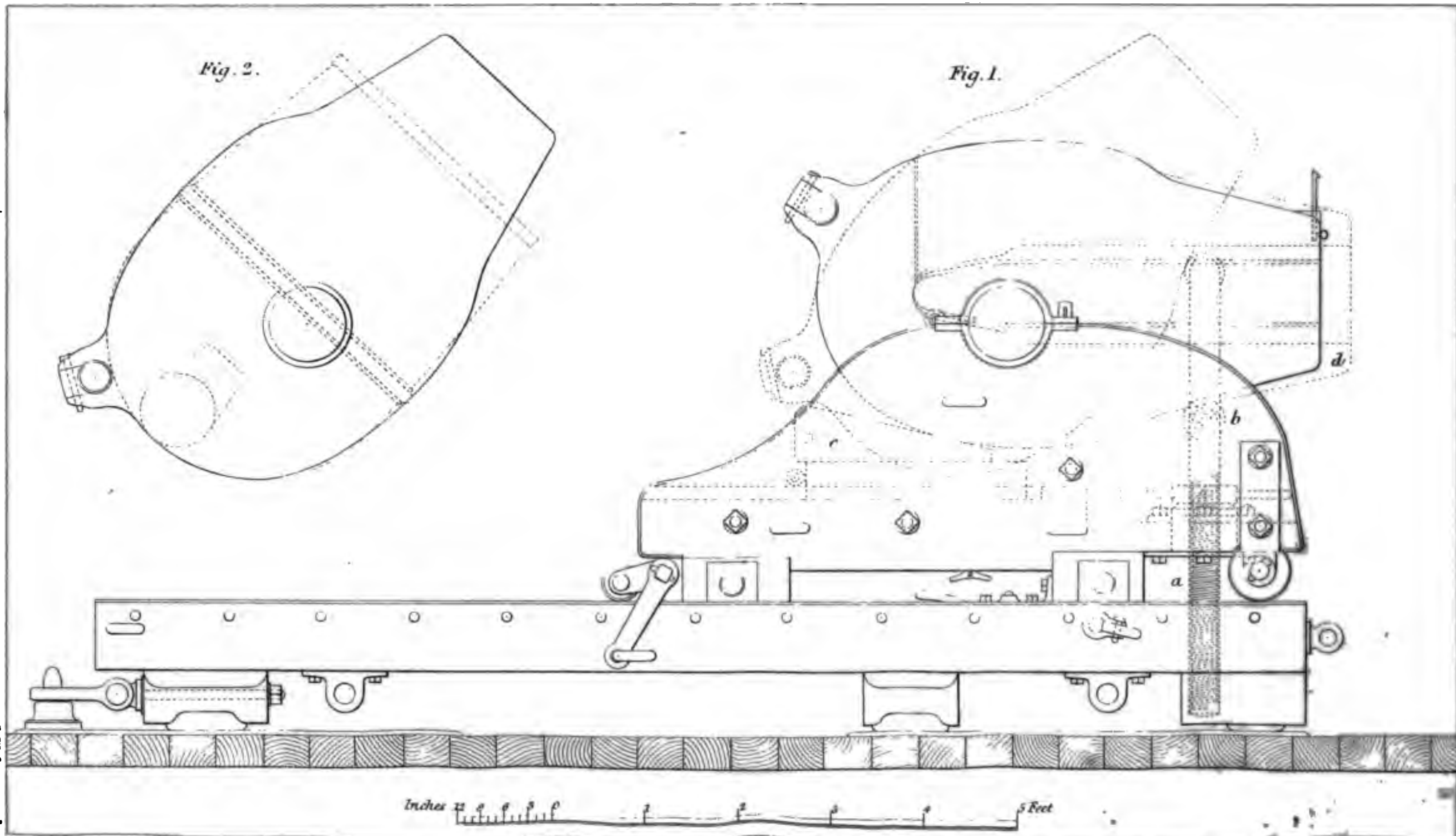

Plate 4.

J. W. Lowry fc

(ADDENDA.)

OF THE METHOD

OF APPLYING

THE PRINCIPLE OF THE RIFLE TO ORDNANCE GENERALLY,

AND

THE DESCRIPTION OF GUN, ETC., BEST ADAPTED

FOR PRODUCING THE

GREATEST PRACTICAL EFFECT.

THE regulation of the turn of the grooves, whether for rifled ordnance or small arms, must depend, not only upon the description of projectiles employed, but also upon the nature of the service for which they are required. An examination of the principle and the effects of the rifle, will make this evident.

By giving to a shot a quick rotary movement about an axis situated in the direction of its flight, each portion of its surface is presented in turn to the same action of the air in such rapid succession that the latter has not time to act upon one part more than upon another, and its action upon the whole

surface of the shot is thus equalized. The velocity of the rotation will, as the shot progresses, gradually be reduced, and its functions thus become paralysed, as it were, by the resistance of the air; so that in an extended flight this velocity may be so much reduced that it will no longer answer the purpose for which it is intended. The only remedy for this, when the shot has to be fired at great elevations, is to increase the turn of the grooves. It would, therefore, be necessary to give a greater turn to the grooves of the description of ordnance required for this purpose, than to those which would (as with small arms) always be fired with less elevation.

Undoubtedly, the greater the velocity of rotation given to the shot in either case, the more accurate would be its flight; but, as great angular velocity, when acquired by means of grooves in the bore of the gun, is attended with a loss of range, the least possible turn that can be efficiently used the better. Other inconveniences, (such as the recoil, and liability of the shot to strip,) have likewise to be taken into consideration, and these occasion the length of the turn to be a matter of great importance.

It will be impossible to decide upon any standard for this turn, until the description of gun from which the projectile is to be fired, as well as the nature of the projectile itself, is known. These two being ascertained, it will then remain to find the length of turn which will best secure a proper degree of accuracy,

with as little impediment as possible to the range and velocity of flight of the shot.

For mortars, which are always fired at high elevations, the turn must necessarily be great, as it is indispensable that the shells projected from them should maintain their accuracy of flight to the full extent of their range. On account therefore of the greater turn than usual, a comparatively low initial velocity must be given to the shell, to prevent the danger of it stripping; for this reason, a shell of a longer or heavier description may be used with greater advantage with these than with any other kind of ordnance, less initial velocity being required for these shells, than for others of less length.*

On the other hand, were it requisite to obtain the greatest possible range in a horizontal direction, or with lower elevations, a less turn would suffice, but a shell of less length must be used, and a higher initial velocity given to it. In this manner, a greater range at the lower elevations may be obtained, and, for a certain distance, a proper degree of accuracy, (the conditions of ordinary rifle firing, which is rarely practised at elevations exceeding 5° or 6°.) But, at greater elevations, the latter part of the shell's flight would not by any means be so accurate, nor would it

* I have given the least turn which can be employed for mortars, with which certain shells three diameters in length, would be used, at page 92.

in this case exceed its former random range, not only on account of the greater mean velocity of the longer shell, but for the reason that, when the turn is insufficient to keep a projectile steady throughout its whole flight, the plane of its resistance becomes greater in proportion as its flight becomes unsteady, and this not only causes deflection, but compels it to suffer a greater resistance from the air. The only advantage arising from the use of a slight turn, and a light description of shell, appears to be, that, at the shorter ranges it could be used with less elevation, for the longer shell of the same diameter will not bear a charge of powder proportionate to its weight, even supposing the gun would stand it; as it will, however, descend to the earth at a less angle, this is almost as great an advantage as the use of a lower elevation.

The above will shew the widely different results produced by giving a shot its initial velocity of rotation by means of a great turn and low velocity, and by means of a high velocity and less turn. The former method is more applicable to heavy ordnance, and the latter to small arms. Care, however, should be taken that the turn and the velocity be not carried to too great extremes in either arm; for in the one, the range itself would thereby be too much diminished, and in the other, the limit of the range at which a proper degree of accuracy would be attainable. It is, probably, the great turn used by Colonel

Jacob, and the consequent great precision of fire obtained, that causes his bullet to appear to have a greater range than the bullet used for the Enfield musquet; for the difference in the form alone of the balls would hardly seem to require so great a difference in the turns employed in his and in the Enfield rifle, though, doubtless, either greater elevations, or larger charges of powder than ordinary are employed with his, to produce the results we hear of. It is partly for the above reasons that I have advocated the use of a rather different kind of weapon to the Enfield musquet for the Rifle Brigade.*

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* See Note, page 28. The suggestion contained in this note was made under the impression that the Pritchett bullet was universally adopted into the service, and the heavier charge was advocated partly with the view of obtaining a greater degree of expansion for the bullet, as well as on account of other advantages; it appears, however, that another description of bullet has been found preferable; this is hollowed out more behind, so as to admit of a wooden plug being placed in it, by means of which the necessary expansion (which apparently cannot be procured with the Pritchett bullet) may be obtained. The only objection to this bullet lies in the fact, that the plug is quite detached from it; this not only tends to produce a certain expansion of the lower part of the bullet previously to its being used, and thus to occasion a difficulty in loading, but also renders it liable to shift its position, or to be blown quite through the bullet when discharged, which latter circumstance arises from the plug or cup being allowed (from its loose condition) to acquire a certain amount of velocity before the inertia of the bullet itself is quite overcome. It appears to me, however, that all these defects might in some measure be remedied, by attaching the plug to the bullet by means of an iron pin, as

For general purposes it is not the greatest range only that is to be desired, but that combined with the greatest possible degree of accuracy. If at Shoeburyness, or elsewhere, the experiments with rifled guns, or the projectiles to be fired from them were, (instead of being made for the purpose of trying certain shot or shells with a particular kind of gun only,) directed to the acquirement of the best description of shell for every different service, and the turn of the rifling best adapted to them in order to procure a standard, much more important and satisfactory data than are now obtained would be secured. For this purpose eight or ten guns of the same calibre might be rifled, each with a different turn; all experimental shells being made to fit that calibre, they might then be alternately fired from each gun. By these means the different effects produced would lead to satisfactory and con-

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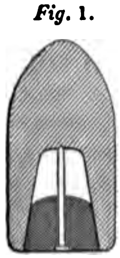
Fig. 1.



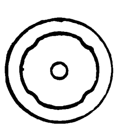


Fig. 2.

shown in Fig. 1, or by the additional use of two or more grooves or guides, as represented in Fig. 2, so that when driven forward, it must necessarily be in a straight direction, and being fixed in the first instance, it could not so easily shift its position or be accidentally driven in, and so cause an unnecessary expansion before it were used; and when discharged, the expansion would (although equally efficient) be more gradual, the velocity of its forward movement being checked by the pin, and the chances of its being forced completely through the bullet thereby considerably diminished. The turn for this, would probably be less than that which is required for the Pritchett bullet.

clusive results. It is in this manner that I have conducted my own experiments on a smaller scale; and, notwithstanding the vague notions which prevail respecting the matter, it will, I am sure, be ultimately discovered that a certain turn answers best for each shot, and that this turn is governed by the circumstances which I have already described; and further, it will be found, that in order to obtain the best results with similar shot of increased size, the decrease in the turn for them does not differ materially from that assigned by the method which I have given for the purpose.

With regard to the latter point, perhaps the most correct way of arriving at the comparative effect of the air upon shot of different sizes, or (if I may so express myself,) the power acquired by shot of different weights of overcoming the resistance of the air, in order to regulate the turn by it, is to compare the differences of their *terminal velocities.*

The velocity of a shot descending through the air by its own weight, will gradually increase until it meets with a resistance from the atmosphere equal to its own weight; the impelling force and resistance being then equal, the shot will continue to descend with the same uniform velocity, which, of course, will differ according to the weight and diameter of the shot, but which is in every instance called its "*terminal velocity.*"

It has been computed that the terminal velocities

of shot bear to each other a ratio about equal to that of the square root of the number expressing the times that the diameter of one contains that of the other, to 1, (very nearly the proportion which I have already given in estimating the difference in the force of the air upon shot of different sizes); thus the terminal velocity of a 3-lb. shot is about 290 feet a second, and that of a 24-lb. shot (which has twice its diameter) about 420 feet; so that if these two shot in falling through the air had each attained its terminal velocity, the smaller would continue to descend with a velocity of about one-third less than that of the larger, the retarding force of the air being, relatively, really that much greater upon it, although previous to their acquiring their respective terminal velocities, the resistance will vary with the different velocities with which they are descending.*

* When shot, similar in form, but of different sizes, are fired with the same initial velocities, the larger will always maintain a superior degree of velocity in proportion to their greater terminal velocities, so that it is not their weight alone which causes their effect to be greater; but their superior velocity adds considerably to their otherwise increased force of impact and general effect. When, therefore, the weight of the gun is limited, and the circumstances under which it can be used, conveniently admit of the employment of greater elevations, the advantages are enormously in favour of a heavy projectile, in preference to those of a lighter kind, used with a greater initial velocity, as (except at short distances) a greater proportionate effect can be produced with a larger shot, and a lower initial velocity.

It is only from a knowledge of the comparative terminal velocities of projectiles, that we are enabled to discover the actual increase of power over the resistance of the air acquired by those of increased size. This is exemplified by the ranges of different sized shot; the range will, as a general rule, be found proportionate to the terminal velocity of each shot, the velocity of projection being the same, although, from different causes, there is occasionally a variation from this. When, however, the initial velocity of two shot of different sizes is below the terminal velocity of the smaller, the difference between their ranges is somewhat greater.*

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* When shot of different sizes are fired with initial velocities *below* their terminal velocities, the greatest resistance which they meet with from the air being only equal to their own weight, the difference between their ranges will increase as the velocities are diminished; and this will arise, not from any difference in the relative amount of resistance suffered by each, but because it will bear a much smaller proportion to the momentum of the larger—or its power of overcoming it, if I may so term it. Thus, a 12-lb. shot, propelled at the rate of 16 feet a second, will meet, we will suppose, with a resistance equal to ¼ oz.; a 96-lb. shot, under similar circumstances, (being double its diameter,) would meet with a resistance equal to 1 oz.: the additional momentum acquired by the latter shot would be out of all proportion to the trifling additional resistance it would encounter when moving with so small a velocity, and it would naturally go much further than the lighter shot—probably nearly three times as far, or nearly in proportion to its greater momentum. These differences however would not affect the regulation of the turn with elongated shot; at all events not in

The comparative terminal velocities of long projectiles of different sizes, supposing them always to move point foremost, will bear the same ratio to each other as those of round shot, provided the flight of each be equally steady; it is for this reason that the perfectly steady flight of elongated shot is of so much importance, for a want of it not only causes more or less deflection, but also considerably diminishes their range.

Now, it is evident, that whatever functions a shot may possess at the moment of its projection, whether of a rotary or progressive nature, they can only be retained by it in proportion to the power which it possesses of overcoming the opposing influence of the air; and both theory and practice make it equally apparent that the comparative power possessed by shot of overcoming the resistance of the air, is in proportion to their terminal velocities. It is therefore the only reasonable basis upon which to establish a rule for regulating the turn for guns of different calibres; for the rotary motion of projectiles, being dependent upon their progressive power, must necessarily be equally affected by the retarding force of the air.

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a manner worth computing, for, (as I have stated elsewhere,) were it even necessary that they should *always* be fired with a very low velocity, they would require a turn as great as, or even greater than, if fired with higher velocities, although the actual velocity of rotation required for them would he less. A fixed scale, therefore, for regulating the turn, according to the size of the bore of thc gun, is not only desirable, but really necessary.

Though a gun, rifled with a much less turn than that given by the above method may, (for reasons before stated,) with a certain description of shot and charge of powder, shew a great range, and even a tolerable amount of accuracy compared with round shot, yet this is no criterion of its correctness or incorrectness as a rule. To test it properly, a gun should be capable of throwing its shot with the same precision as the Enfield rifle, (or any other which may be taken as a standard,) not at the same distance only, but at ranges for which the same *elevation* would be required for each; that is to say, a gun with a bore 4·2 inches in diameter (or 9-pr.) should, at about 2500 yards, (a shot being fired from it, similar to that used with the Enfield rifle,) strike a 12 foot target with the same certainty as the Enfield rifle at 900, the same elevation (about 4°) being required for each. Until this, or something very near to it, can be done, the proper method of applying the principle to cannon will not have been thoroughly established; for although the larger shot, on account of its long flight, might be supposed subject to a greater lateral deviation, being exposed for a longer period to the action of the wind, yet its greater weight would tend to decrease that deviation, and may be assumed to fully counterbalance it. To attain this necessary accuracy, I think it will be found that a turn must be used, similar to that given at page 92; although to enable the larger shot to maintain the

same accuracy as that of thc Enfield rifle, at the shorter distance only, a turn in the same number of diameters would probably suffice.*

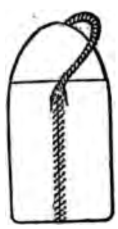
With hollow iron shells of the same diameter, however, this accuracy could not be obtained at a like distance, for, as a want of concentricity is a main cause of the deviation of shot, and is much more likely to exist in hollow iron shot than in others, these would require a somewhat greater turn to remedy this, as well as their deficiency in weight.†

Due allowance being made for these circumstances, the same accuracy should be had with them at about 1800 yards, (their diameters, and the elevation at which they are fired, being the same,) as with the others at the 2500 yards range. This has reference to iron shells of about twice their diameter in length, and less, such as could be fired with the same velocity as the Enfield bullet. With compound shot, where a quantity of lead would be employed in their

* With the military rifle, forty years ago, one whole turn in ten feet only, and a very heavy charge of powder were used, and it was found upon trial to shoot as accurately at 100 and 200 yards, as others with four times the turn; but the latter were found so immeasurably superior to it at all distances beyond this, that the turn was afterwards considerably increased.

† Their form, however, will permit of the centre of gravity being placed more forward in them than with solid leaden bullets; this will be found (as regards the turn) to counterbalance, to a certain extent, their deficiency in weight.

make, a greater range could of course be had, and also a higher initial velocity might be given. I am not aware whether the effect of it has ever been tried or not, but an elongated shot, entirely of lead, fired from a rifled cannon (say an 8-inch gun of 65 cwt. bored to a 6-inch) would no doubt prove a very destructive missile in naval engagements, and would not only cause much greater damage to a ship than an iron shot of the same size, but, on account of the less elevation required for it, would, at long ranges, give an immense advantage to a vessel employing it. Not only would the superior precision with which it could be fired render it useful in crippling a ship, but, upon striking a mast, it would do more towards carrying it away, for it would both give a more serious wound, and from its want of elasticity, cause a much greater concussion. One gun firing such shot, for a chaser in the bows of a ship might do good service; and if each shot had a well greased leather casing upon it, (as shown in the cut,) they



would not lead or foul the inside of the gun much. The shot to be employed for the gun which I have described, would weigh about 96 pounds, and with a turn in 24 feet, and fired with a charge of ten or twelve pounds of powder would, at 5° of elevation, range (according to the ordinary computation,) to about 3000 yards, and with the accuracy of an Enfield rifle; though, probably some slight additional

elevation might be necessary, on account of the greater comparative velocity of rotation of the larger shot.

The following is a scale of the different lengths of the turn required for guns of different calibres, according to the method already given, taking the Enfield rifle as a standard, and supposing leaden shot of a form similar to those used with that rifle to be employed. The fourth column shews the turn required for mortars or short howitzers of corresponding calibre, from which iron shells (similar to those represented in Plate I., and three diameters in length) would be fired.

Description of Guns.	Diameter of Bore.	Corresponding ordinary length of turn for Leaden Shot.		Minimum length of turn for heavy iron shells for Howitzers or Mortars.	
	ins.	ft.	in.	ft.	in.
6-Pr.	3·66	16	4	11	6
9 „	4·2	17	3	12	0
12 „	4·62	18	3	13	0
18 „	5·29	19	8	14	0
24 „	5·82	20	6	14	6
32 „	6·41	21	6	15	3
42 „	6·97	22	6	16	0
56 „	7·65	23	6	16	8
68 „	8·12	24	4	17	0
8-Ins.	8·	24	3	17	0
10 „	10·	27	0	19	0
12 „	12·	29	6	20	9
13 „	13·	30	6	21	6

In forming a rough estimate of the comparative turns required for different kinds of projectiles, it may be taken, as a general rule, that for shot of the same length and diameter, but of different density, it will vary about as the square roots of their weights, the less of course being required for the heavier shot or shell. For iron shells of less length than the above, the turn (being governed by the relative proportion of their weight to the retarding force of the air upon their rotary movement generally) may also, to a certain extent, be reduced. In either case, however, the stability, or position of the centre of gravity in the shot, must be the same, or nearly so.

The more closely this subject is examined, the more prominent appear the advantages which would accrue from the adaptation of elongated shells to *mortars*. The terminal velocity of these being so much greater than that of spherical shells of the same weight, they would not only have a greater range with a smaller charge of powder, but would also have an enormously increased force of impact in their descent. The precision with which they could be thrown would also be greatly superior on account of their rotary movement. This is of the highest importance; and such a shell as I have described can be fired with a degree of velocity which, whilst sufficient to give it an extended range, shall at the same time allow the resistance of the air upon it to be so reduced that it will describe a line of flight more nearly

approaching to a parabolic curve than that of spherical shells, even when the latter are fired with lower velocities, and much more nearly so than when they are fired with the ordinary service charge. For this reason, the heavier the description of shell, the higher is the elevation at which an increase in its range can be obtained. When we consider not only the different curves described in their flight by round shot of equal sizes, but also the variety of curves described by shot and shell of different sizes when fired with different velocities, (all of which circumstances vary the precision of the fire,) the value of these facts will be appreciated.

When a heavy description of elongated shell is employed, although the charge of powder may be of reduced quantity, the strain is great upon the gun, owing to the longer time which is taken in overcoming its inertia. This is consequent upon the reduced section (as compared with round shot of equal weight) of that portion of its surface which receives the first impulse from the powder, which of course is less, in proportion as the shot is longer; the fluid generated by the ignition of the powder is consequently allowed (with an expanding shot) to accumulate behind it, and thus occasions more or less strain.* It was with the

* I should imagine, for this reason, that it would be almost impossible to use gun cotton with these shells; in fact, a coarse slow-burning powder would probably be the best to use with them.

view of alleviating this strain (as well as to ensure a true direction of flight) that I at first caused shells to be made with the ring, as shown in Plate I. This, being pushed forward against the fore part of the shot, and thus yielding to the pressure before the inertia of the shot itself is overcome, relieves the strain which would otherwise be attendant upon its great length. I have frequently fired shells of this kind of three-quarters of a pound weight from a wrought iron gun weighing 5½ lbs., with charges varying from $\frac{1}{24}$th to $\frac{1}{8}$th of their weight.

In the employment of artillery, to obtain the utmost effect with the greatest economy of time, labour, and expense, both in their construction and in their use, is a chief consideration. If the reader will refer to Plate IV. (Fig. 1), he will there see the description of gun with which this end may probably, in my judgment, be the best attained. It may be called either a mortar or howitzer, as it could be used as either. It is 5 ft. 4 ins., in length, and of rather greater weight (120 cwt.) than a 10-inch solid shot gun; it has an 8-inch bore only, but will throw a shell of 250 lbs. weight, with a charge of 10 or 12 lbs. of powder. It might be employed equally as a siege gun, or for the deck of a ship or gun boat. It would, as a mortar, besides an enormous increase in range, have the advantage in almost every other respect over the ordinary 13-inch mortar, (the weight of which it would

not much exceed,*) and could also be used with very great effect horizontally, as it would even then have a greater range than a 10-inch gun, and throw a shell of nearly three times its weight; and, although for short distances it might require a greater elevation than the 10-inch gun, yet, the mean velocity of the flight of such a projectile being so much greater, the mean elevations required for it would be less. It should have one whole turn in 17 feet, (though probably one in 15 feet would be better,) in order to insure a perfectly steady flight throughout; with such a gun as this, (when fired with the above-named charge of powder and projectile,) a range of 8,000 yards would probably be attainable.

It is an important feature in the use of the heavy shells that the length of the bore of the piece from which they are propelled may be considerably reduced; for the velocity which is necessary for them for ordinary purposes, can be given with a bore seven or eight of their diameters in length only, and owing to their own great length, they acquire as true a flight as they would have if fired from a bore twelve or fourteen diameters long. This was tried, by gradually reducing the length of an experimental gun from eighteen diameters of the bore to seven. The friction in their

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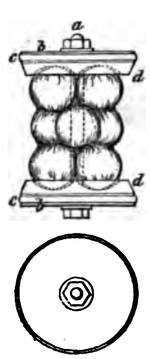
* Fig. 2 in the engraving (Plate IV.) will show the respective dimensions of the above gun, and those of a 13-in. sea-service mortar.

passage out of the gun is also much less when its length of bore is reduced.

Their want of length, however, would quite preclude the possibility of these being used as broadside guns, but on the deck of a large frigate one or more of them would prove a formidable addition to her armament. If I may be allowed an opinion, I should say that shell guns—that is, such as cannot be used for solid shot as well, should be the exception, and not the rule, both on account of their less range and of the loss of time in loading them. No ship ought, I should imagine, to be armed entirely with them, unless they were of the heaviest kind possible, and she could command very great speed, and so choose her own distance for engaging the enemy.

The above form of gun may also be employed on a smaller scale, as a field howitzer, to throw a shell of 32 lbs. weight. In this case it might be mounted on a carriage similar to that shown in the frontispiece. On account of the reduced length of the bore, such a gun would be about the same weight as a 9-pounder brass gun, or 24-pounder howitzer. Should it be necessary to use grape shot with it, several plans might be devised for doing so without injuring the grooves, and probably even such as might render it advantageous to use such shot with rifled guns. The accompanying woodcut will shew one method of accomplishing this: *a* is an iron spindle passing



through the entire body of the shot, with a nut to screw on at either end; this should be rather smaller at the two ends where the plates are situated, so as to form shoulders, to prevent them being jammed against the shot; *b b* are two thin circular iron plates;* *d d* two iron plates of the same diameter, but thicker, and hollowed out on the side next the shot. These will vary in diameter according to the size of the gun, and in proportion to the windage allowed. *c c* are two leaden plates, placed at either end between the iron plates, and slightly rounded out from the edge in order to project a little beyond the latter, which should be loose on the spindle. The whole may be screwed tightly together by means of the nut at either end of the shot, which may be arranged in the usual manner round the spindle. A layer of felt, or even a thin plate of copper for iron guns, might be used instead of lead; so that, even supposing no advantage to be gained by the rifling, no injury would happen to the grooves, as the pressure of the discharge at one end, and the resistance of the air at the other, would cause the lead or felt to be compressed in such a manner as to fill the bore, without allowing the iron plates to impinge on it at all.

Some mention has been made of a light description of field piece, used in the Prussian service, which will

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* The top plate might be made of a hemispherical form, if thought expedient, and not too heavy.

give a shot of 1 lb. weight an effective range of 1000 yards. If it were found advisable to adopt such a weapon, a wrought iron gun (similar to the one I have described) might be made sufficiently light for two men to draw and work, and would throw a shell from 3 lbs. to 6 lbs. weight with accuracy, to a much greater distance than 1000 yards; and by simply placing a percussion cap upon a nipple at the fore end of it, (which could be done when loading,) the shell would be made to explode upon meeting the first obstacle, however slight.

If a very light gun should be required, it might even be made of twisted metal, like an ordinary fowling piece.

I have observed, that nearly all elongated shot are made with their fore ends more or less pointed. This appears contrary to the received notions of the effect of the resistance of the air, and is to be regarded rather in the light of a vulgar error. It was proved by experiments made with the whirling machine, constructed by Dr. Hutton, that the sharp ends of solids of equal diameter, suffered more resistance than their hemispherical ends, the difference not being very great; while the resistance on the plane ends of the same was found to be more than double either. Now the retarding effect of the air upon a shot is dependent more upon the weight or density of the shot than upon its form, its diameter remaining the same; if therefore the resistance offered by the hemi-

sphere is very nearly the same as, or (which is doubtful) even somewhat more than, that offered by the form called the curve of least resistance, the superior weight of the hemispherical end, in shot of equal length, would cause the retarding force of the air to have less effect upon it, and also (which is of importance with long shot) place the centre of gravity more forward.

The construction of the fore end of a long projectile is of little moment (provided it be smooth and convex) compared with that of its hinder part, for on the latter depends the truth of its flight; and the comparative resistance of the air upon the round and conical ends of shot, exhibits a difference so trifling, that it is a matter of but slight importance which form is preferred.

After a shot leaves the gun, the action of the air affects it in a threefold manner; in the first place, by offering a resistance against the fore end, caused by its flight in a forward direction, this being in proportion to the surface contained in the diameter of the shot, and as the *square* of the velocity of its flight; secondly, by a pressure upon its longitudinal surface, which is *as* the velocity only with which it moves; and, thirdly, by a pressure against its under surface, produced by the falling movement arising from the action of the power of gravitation, which is exactly the same as it would be subject to on falling to the ground under any other circumstances.

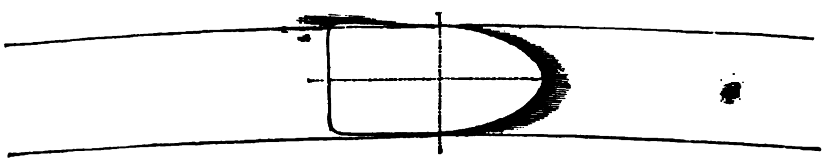
The resultant of these opposing forces is an oblique pressure upon the fore and under part, (I am putting

the case of a projectile of which the centre of gravity is not in the fore part,) and is attended by a comparative freedom from, or at the most, a diminished pressure upon the upper portion of the shot's surface.* The direction of the pressure upon the under surface of the shot varies with the angle at which it is fired, and only when it rises or falls perpendicularly to the earth's surface, is it directly upon its extreme end. This oblique pressure is the chief cause of the deflection of projectiles generally; and although upon those which have a rotary movement about an axis in the direction of their line of flight, its effects are much less apparent, they can, nevertheless, only be completely prevented by forcing the fore end of the shot continually in the direction of this pressure, so that its diametral surface should be opposed to it only.† This can be done, either by diminishing the weight of the hinder part of the projectile (so as to allow of its having a greater length behind its centre of gravity), or by increasing the resistance of the air upon it by means of projections behind its centre of gravity, placed obliquely in a longitudinal, (similar to those upon iron shells generally,) or in a transverse direction; (neither of these latter methods, however, are to be recommended, as they would, to be effective, too much diminish the range); the retarding force of the air will thus be greater upon the part behind the centre of gravity than

* See Figs. 1 & 2., Plate III. † See Figs. 3 & 4, Plate III.

upon its fore-part, and the former will be gradually retarded in the descent, and so continually keep the longer axis of the shot coincident with its line of flight.

Besides the above-mentioned different actions of the air, there is (with long shot which fulfil the last-named condition) also another, which arises from the circumstance that the line of flight described by a shot is a *curve*, whilst its axis in the direction of its flight may be described as a *straight line*; so that, this being longer than its diametral axis, when the fore part of the shot is forced in the direction of its flight, the resistance which it meets with, lying, of course, in that direction,* there will be a corresponding pressure upon the upper surface of its hinder part (*see* diagram), which will tend to steady, as well as to prolong its flight, in proportion to the length of the shot behind its centre of gravity.



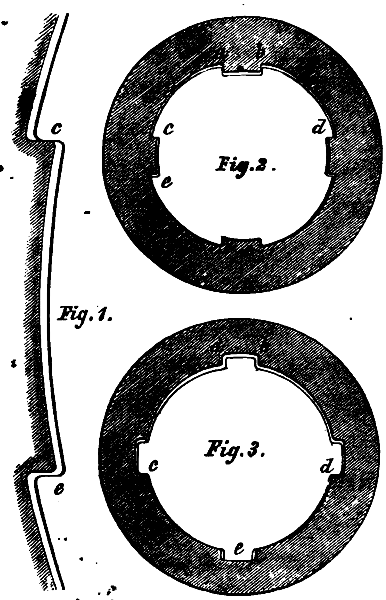
The action of the wind across their path is the only other cause of the deflection of shot which have a rotary motion about an axis coincident with their line of flight; this, however, can be allowed for in the aim. With respect to the deflection of shot to the right or left in the direction of the turn of the

* See Plate III.

grooves, which often happens even when the gun is laid straight for the object, it is simply a sign, (when the centre of gravity is forward in the shot,) that the velocity of the shot's rotation is not sufficient; but when this is perceptible in a shot, for which the velocity of rotation may be supposed sufficient, but in which the centre of gravity is coincident with, or behind its centre of figure, it arises from the axis upon which it rotates losing its coincidence with its line of flight: this is what the French term "*derivation*."

Though, doubtless, the forms of projectiles will undergo many modifications in order to adapt them to the different requirements of war, still they must essentially resemble each other, as, for practical purposes, there is little to be learnt respecting the laws which govern their flight, notwithstanding that the theory of the resistance of the air has been found so difficult of complete solution. Hitherto, no shot or shell of an elongated form has been found for cannon, of such acknowledged superiority as to cause it to be adopted into the service; for, unfortunately, those with which the best effect is to be obtained, do not appear so well adapted for practical purposes, being universally those of a compound of lead and iron. The question, therefore, for consideration is, whether greater range, precision of fire, and facility of loading, with the use of less powder, and the power (with mortars) of using them at greater elevations, does or does not counterbalance the disadvantages attending their use.

Should the inconveniences attending the use of compound shells be considered (which is difficult to conceive) really insurmountable, and cast or wrought iron shells only be employed, I would suggest, in order to afford a partial remedy to the defects arising from their not completely filling the bore of the gun, that the ordinary method should be reversed, and that the grooves should appear as it were upon the shot, and the projections in the bore (*see* the diagram Fig. 2, p. 104). This idea in itself is nothing new, but I mention it as having this advantage, that when the bore contracts from the expansion of the metal after firing, the contraction would be less sensibly felt were it made as at *a b* in Fig. 2, than as at *a b* Fig. 3, and less windage might be allowed at these points; so that if the grooves or projections are cut, as here shown, in a line at right angles with each other, the shot (due allowance being made for it to be pushed easily backwards or forward) would have



its longer axis more nearly coincident with that of the bore, the shot resting upon the two points *c d* (as in Fig. 2) only, instead of upon three as at *c d e*, (in Fig. 3,) as would be the case were an equal quantity of windage allowed at every part. I am, of course, supposing that the contraction of the bore when heated would not allow of the windage being reduced at these points when the grooves are constructed in the manner represented at Fig. 3. If, however, it were found that the contraction would permit of this, the advantages to be obtained by a reduction of windage at these points would, of course, hold good in either case, and it would then signify little whether the projections were placed upon the shot or in the bore of the gun, provided the windage were lessened at these points. Fig. 1 represents, in full size, a portion (*c e*) of Fig. 2, supposing the bore to be 9 inches in diameter; the other figures, being on so small a scale, are necessarily rather exaggerated.

But, although by a nice calculation of the contraction and fouling of the bore, and with care taken in their construction, the incorrectness of the flight of this description of shot may in some measure be lessened, yet the difficulty which must always attend loading with them, almost seems to forbid their use with any description of ordnance but mortars, or guns which would be used at long ranges only. By having the centre of gravity as far forward as possible, the flight of these shells would be improved, as the in-

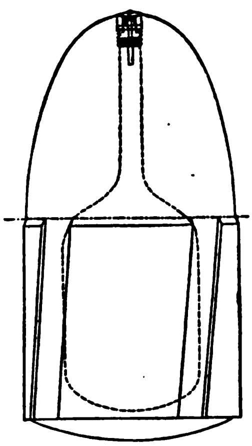
creased retarding force of the air upon their hinder part would tend to correct the unsteadiness arising from their not completely fitting the bore of the gun; acting in some measure as the feathers upon an arrow.

These homogeneous shells could never be used with brass, or scarcely even with wrought-iron guns; none but those of cast-iron would be able to resist for long the effects of the friction produced by them; for although the friction of lead upon either of these metals may retard the passage of the shot out of the gun in as great, or even a greater degree, being distributed over the whole surface of the bore, still the effect of the friction of iron shells would be much more damaging to the grooves, both on account of their hardness, and because they impinge upon one part of the bore only.* By having the projections

* Whatever advantages an elliptical bore may be considered to possess when used for small arms and leaden bullets, they certainly do not exist when this principle is applied to cannon and iron shot, for the latter are not only liable to shift in the bore, to a much greater extent than when the grooves are cut at an angle (*see* Figs. 8 and 9, Plate II.), but there is also a constant risk of their jamming, (which is impossible with the others,) and thus bursting the gun. The polygonal bore, or triangular-grooved rifle, must also, (when non-expanding shot are used with it,) labour under the same disadvantage with regard to the liability of the shot to shift its position before leaving the gun; under any circumstances the advantages to be gained by this description of groove appears very doubtful, and the friction suffered by the shot after leaving the gun must, I should think, be greater than when the gun is rifled in the ordinary manner.

or grooves of the shell (as the case may be) lined with copper, or some softer metal, the evil effects might be lessened; but, under any circumstances, the friction of these shot must always be more damaging to the gun than those of a compound of lead and iron.

The gun represented in Plate IV. is equally adapted for iron shells, as well as for those of which a description has already been given; but, in the former case, the bore should be 9 inches in diameter, instead of 8, and the shell of the form shown in the accompanying figure; its weight would be rather less than that of the other, although the charge required for it would be greater; the escape of the fluid being very great with long shot, from the windage; but this the gun would bear, as on account of the windage, and of the larger diameter of the shot, the strain



upon it generally would be less. The length of the turn required for it would probably be nearly the same as that which is given for a 10-inch leaden shot in the table at page 92, as the difference in the position of the centre of gravity would, in some measure, counterbalance the deficiency of weight in the iron shell.

The distribution of metal in this piece of ordnance, and the general construction of it, is the result of some personal experience and a careful consultation of the different data procurable from practical and scientific sources; a slight addition to its length might be desirable (*see* dotted lines (*d*) Fig. 1, Plate IV.) if bored for a 13-inch mortar; but as this would increase the weight considerably with a bore 8-in. in diameter only, it would be a question for military authorities, whether the advantages attending such an addition would compensate for the greater weight; of course, were the gun to be fired at elevations not exceeding 12° or 15°, a reduction in the thickness of the metal at the breech might be made, and its length could, therefore, be increased without materially increasing its weight; but the small additional range acquired by this, with the description of projectile which I propose using with it, would not, I think, by any means compensate for the loss of the advantage of its employment at the greater elevations.

It will be seen, on referring to the engraving, that the gun is elevated at the muzzle by means of a screw and roller (*a* and *b*), so that by shifting the quoin (*c*) at each degree of elevation, the gun is continually supported at three different points. The rest of the carriage is of similar construction to the ordinary gun-carriage used for the heavy deck guns of a ship. If thought preferable, or if the recoil should be considered too great for the foregoing arrangement, it

might be mounted somewhat in the manner of a sea-service mortar. I think it probable, however, that with this weight of gun and low charge (10 or 12 lbs.) of powder, the recoil would not be too much (with Fergusson's compressor) to allow of its being mounted as an ordinary deck gun.

This description of ordnance might be employed as a substitute both for sea-service mortars and shell guns, when the latter are used in gun boats, so that one description of vessel only would be necessary—the nature of the gun allowing of its being employed for either service, thus combining simplicity with great effect.

I think it would be very desirable to have all guns for elongated projectiles of an uniform character, and, with a view to the employment of the heaviest kind of shell possible, of a description similar to the above; for whether it be for the destruction of men or of material, this description of shell would always prove the most effective; and if they have the disadvantage of requiring a greater elevation, it is fully counterbalanced, in their case, by the angle of the projectile's descent being less.

It appears altogether inexpedient to use rifle guns for the broadside armament of ships or floating batteries; for, what with the delay caused in loading them, if iron shells are used, and the weight of metal required in the gun, for expanding shells, they could not be employed with greater general effect

than those in ordinary use, especially now that so much perfection seems to have been attained with Moorsom's percussion shells. The same objections would hold good with respect to siege guns, for operations on land. For these, such a gun as I have described might prove very serviceable, as it could be used either as a mortar or howitzer, as circumstances might require; and, for the reasons which I have just mentioned respecting the angle of the projectile's descent, a gun of this kind, of the dimensions given at page 97, would be much more effective for field service in every respect than another, from which a lighter description of shell only could be fired.

Of course, before so great an alteration in artillery as this could take place, it would be necessary to submit its merits to the severest tests; but I feel assured they must result in the conviction, that it is the proper method for turning this description of projectile to the best account, and for simplifying its use.

FINIS.

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